THE SIMULATION AND ANALYSIS OF ORGANIZATIONAL STRUCTURES AS COMMUNICATION QUEUEING SYSTEMS

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THE SIMULATION AND ANALYSIS OF ORGANIZATIONAL STRUCTURES
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CHAPTER I

INTRODUCTION

Background and Description of the Problem

One of the most critical processes in human relations is communication. This is due mainly to the important role that communication plays as a primary medium of social interaction. There are several functions that communication performs in such interaction, including the conveying of information and directions.

A very common form of social interaction is that carried out by organizations. The concept of organization can be viewed from different perspectives. In an operational sense it can be considered as the coordination of activities of people, directed toward the achievement of some common objective. One can also view the organization as "a group of people related one to another in some authority-responsibility relationship, the essence of which is depicted by an organization chart"[53]. For the purpose of this study, however, the organization will be analyzed based on the last definition. Regardless of the point of view, organizations are said to be goal directed, and communication is one of the means by which rational management objectives are achieved.

Basically, organizational communication consists of various message sending and receiving phenomena, influencing organizational positions in which individuals work toward common goals. Furthermore, the purpose of organizational communication between individuals in their working for the achievement of organizational goals is precisely to facilitate coordination.

Every communication system in an organization must be composed of three irreducible elements [45]:

1. Sources for generating information and receivers for assimilating it.

2. Vehicles for conveying information.

3. Channels for distributing information.

The study will be concerned primarily with the third element, that is, with the channels for distributing information.

The proper manipulation of the above three elements is the key for a good communication system and to its inherent advantages in an organizational structure. Thus, effective communication could be credited as a prime factor in the attainment of high levels of organizational effectiveness.

For an organization to perform its functions, there has to be a system of communication. This system is usually based on a hierarchical structure that enables the organization to set policies concerning priorities and directions in the flow of communication messages, and also permits the establishment of good vehicles and channels for distributing such information.

Except for a few organizations, establishing executive positions with key responsibilities related to the administration of communication systems is not a widely used procedure. Actually, most organizations do not even explicitly specify their policies concerning communication. To the extent that communications follow formal organizational lines, however, there must be a relationship between organizational structure and the effectiveness of that structure as a communication system.

The existence of a hierarchical structure within an organization (formal system of authority and communication) imposes the necessity of having people subordinated to others, some receiving orders (subordinates) and some processing information generated by the subordinates which in turn is a consequence of the order generation. Some individuals (i.e., middle managers) serve as both superiors and subordinates at different times.

It has been found that a very common source of inefficiency in an organization is caused by the delegation of excessive responsibility to a supervisor by making him directly responsible for too many subordinates. These inefficiencies are due to the limitations on the amount of information that a person is able to receive, process and remember.

For example, if an executive's span of control (i.e., the number of individuals reporting directly to him) is too small, he/she may tend to exert excessive supervision over the subordinates which will very probably cause problems, while the ability of the executive is not fully utilized. Besides, there are cost implications of hiring more managers and of creating an unnecessarily bureaucratic system. On the other hand, if the span of control of an executive is too broad, he may not be able to handle all subordinates properly and a lack of control and coordination could result. Thus, a correct span of control is necessary for an organization to perform its functions efficiently.

The problem of finding the correct number of subordinates has created discussions among several theorists. Their approaches have been somewhat oriented toward behavioral sciences, emphasizing such phenomena as group dynamics, individual participation and satisfaction, etc. Nevertheless, the problem of finding a proper way to analyze the implications and consequences of selecting a given span of control in an organization still remains.

Objectives of the Study

The overall objective of the study is to demonstrate the modelling and simulation analysis of organizational structures as communication queueing systems. This overall objective can be divided into three specific sub-objectives:

1. To develop the conceptual model of organizational structures as communication queueing systems.
2. To illustrate the computer simulation of organizational structures as communication queueing systems.
3. To employ the simulation methodology to evaluate and analyze the communication queueing performance of a simple, hypothetical organization under several alternative structural arrangements and several sets of communication parameter values.

The third sub-objective requires further amplification. The hypothetical organization contains 16 identical positions at the operative (lowest) level and one top-level manager. The alternative structural arrangements to be analyzed for this organization are developed by varying the number of managerial levels and the span of control at each level. The eight symmetrical structures that can be developed for this organization are described in detail in Chapter III.

The specific communication parameter values to be manipulated in the simulation analysis are:

1. The rate at which messages are generated in the system.

2. The rate at which messages are processed by each position in the structure.

3. The probability that, after a given message has been processed by an aorganizational position, it will be terminated rather than being transmitted to another position for further processing.

The four specific sets of parameter values used in the simulations are presented and discussed in Chapter III.

The criteria on which the communication queueing performance of the organization is to be evaluated are as follows:

1. The mean and standard deviation of the distribution of message throughput times (i.e., the time from the initial generation of the message to the completion of all necessary processing of that message).

2. The average lengths and waiting times for queues of messages awaiting processing at individual organizational positions.

3. The utilization of the organizational positions, measured as the percentage of time that the position is busy processing messages.

A fourth criterion, which is not a matter of queueing performance, but which must be considered in the evaluation of alternative structures, is the personnel-related cost of each structure. In the interest of including cost as a criterion for comparison, Chapter IV presents an arbitrary, but reasonable formula for estimating the personnel-related costs associated with each of the eight alternative structures.

Chapter III presents and discusses the implications of additional assumptions that were made to limit the complexity of the model and to enhance the comparability of the simulation results obtained for the various structures and parameter settings.

Two specific research questions are addressed in the analysis of the simulation results for the hypothetical organization:

1. What are the relative sensitivities of the various queueing performance criteria to changes in (a) organizational structure, and (b) communication parameter values?

2. What specific aspects of organizational structure have key impacts upon the various criteria of communication queueing performance?

The applicability of the simulation results obtained in this study are clearly limited by both the methodology and the simplifying assumptions. Still, it is anticipated that general insights may be developed that could be helpful in the design of organizational structures. Perhaps more important, the demonstrated methodology, with appropriate extensions, may prove to be a useful device in the analysis of formal organizational communication systems.

CHAPTER II

LITERATURE SURVEY

This chapter presents a review of existing literature relevant to the present research. It is organized around four topic areas: (1) span of control; (2) communications flow; (3) organizational analysis; and, (4) systems theory and its contribution to organizational analysis. These areas have generally been treated separately in the literature.

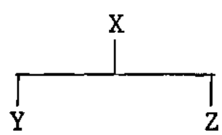
Span of Control

A manager's span of control is defined as "the number of subordinates reporting directly to the manager"[32]. The width of the span influences the effectiveness of organizational structures.

In 1949, Henri Fayol [19], an early proponent of a "science of administration", stated that "whatever his rank, a man has only to command a very small number of direct subordinates, usually less than six, except that a foreman, who is dealing with quite a simple operation, is in direct command of 20 or 30 men."

A classical span-of-control theorist was Graicunas [23], who examined several types of relationships encountered in an organization.

Given the structure:



the types of relationships are:

1. Direct-single relationships.

    X to Y
    X to Z

2. Direct-group relationships.

    X to Y with Z present
    X to Z with Y present

3. Cross relationships.

    Y to Z
    Z to Y

Graicunas developed a formula that gives the maximum number of all three types of relationships possible:

$$N(2^{N-1} + N-1)$$

where N is the number of subordinates.

For a manager with three subordinates, for example, a minimum of three and a maximum of 18 possible relationships exist. The degree to which the work done by each subordinate comes into contact with the work done by others determines how closely that maximum is approached. At the lowest level of the organization, the work done by the workers in most cases does not involve much contact with other workers. Therefore, cross or group relationships do not occur very frequently permitting the size of the span to be quite wide. On the other hand, at high levels of the organization, the number and frequency of cross and group relationships are necessarily much increased because of a larger measure of interaction among positions.

These concepts have been discussed by other classical writers who generally agree that span of control is very likely to vary at different levels in the organization. R.C. Davis has indicated that there is a very clear distinction between what he calls "executive" span and the "operative" span referring to the middle upper organizational levels and to the lowest level respectively [16]. In general he concludes that the span should become narrower as the organizational level increases. Urwick, on the other hand, stated in 1933 that the ideal span for top management should be four, but that at the supervisory level the number may be eight to twelve [56].

Some other writers reject the notion that span of control is most closely related to organizational level, but believe that the span of control depends on the type of situation and supervision required. Stieglitz describes an approach taken at Lockheed for determining the "optimum" span of control [51]. Stieglitz lists the factors that should be taken into account in determining the optimum span:

1. Similarity of function performed by the various components.
2. Geographic contiguity: physical location of components and personnel reporting to a principal.
3. Complexity of functions performed by the components.
4. Direction and control: the nature of the personnel reporting directly to the principal.
5. Coordination: the extent to which the principal must exert time and effort to coordinate.
6. Planning: time, complexity and importance in planning future programs.
7. Organizational assistance: the help received by the principal from subordinates.

By combining all factors, Stieglitz develops what he calls a "supervisory index" which is used to measure the "optimum" span of management. An illustrative application of the supervisory index was made by Barkdull [4].

The span of control, as a principle of classical management, has been subject to a great deal of controversy. Some authors hold that there is a limit to the span of control, but that this limit varies somewhat according to different conditions. Some others believe that the idea is fallacious in itself. Soujanen argues that the notion of an "optimum" span of control is meaningless and that the principle is no more than a management fable [48]. Dale [15] supports this position. He reports that the number of subordinates in successful companies is almost always much higher than what is stated by classical theory. However, Urwick [56] defending the classical position remarks that Dale's measure of span of control is wrong since he included subordinates having access to the supervisor and not only those reporting directly to him.

The practices currently followed by successful organizations do not conclusively prove or disprove the validity of the span-of-control theories. In 1967, Udell performed a survey to determine whether the variables employed by Lockheed really corresponded to differences in span of control at 67 Wisconsin and Illinois manufacturing companies [54]. It was found that successful firms had very similar spans of control, whereas unsuccessful firms had broader or narrower spans of control. The conclusions of the tests of hypotheses were: (1) personal assistants, similarity of functions supervised and competence of subordinates are associated with larger spans of control; (2) geographic dispersion, need for coordination, need for control and close supervision of subordinates, formalization of job relationships, and non-supervisory duties of the manager do not seem to affect the span of control; and, (3) the competence of the supervisor seems to increase his capacity for a broader span of control.

Abulela investigated the importance of the direct group relationships and the cross relationship between the supervisor and his subordinates (concepts introduced to the literature of this field by Graicunas) as determining the size of the span [1]. The study involved only large companies - ten in the manufacturing and five in the non-manufacturing field. Some of the conclusions are that direct and cross relationships are not significant factors in the relationship between the superior and his subordinates; neither the type nor the state of industry exert a great influence on the size of the span. Abulela concludes that staff may influence span of control, but the delegation of authority and responsibility have little influence. A final conclusion of this study was that a chief executive usually spends more time with line employees individually and with staff employees in direct group relationships.

Other authors have also conducted research on span of control. For instance, in 1961 surveys of several businesses and universities yielded some important conclusions about size of the span [17]. In summary, these surveys indicated that spans are not constant but they increase slowly as the size of the organization increases.

Finally, since the span of control principle is necessarily based on psychological concepts, it is important to mention the behavioral research literature. In 1956 Miller conducted experiments by representing individuals as channels of communication receiving stimuli and transforming them into subjective reports [40]. His conclusions are the following: (1) the span of immediate memory can include about seven items; (2) the span of absolute judgement (as measured by auditory, visual, and olfactory discrimination) can distinguish about seven different categories; and, (3) the span of attention can encompass about six objects.

Hare conducted research on group size and concluded that as group size increases, "there is a more mechanical method of introducing information, a less sensitive exploration of the point of view of the other, and a more direct attempt to control others and reach a solution whether or not all group members indicate agreement" [27]. He also suggested that as group size increases, members feel less directly involved in task success.

Group size is definitely involved in the participation of individuals in the work. Two important studies were done in this area in 1958. A study by Slater focused on analyzing interactions on groups of different sizes concluded that the level of inhibition (reflected in the way the individual expresses dissatisfaction and disagreement) tended to increase as the group size decreased [47]. A finding consistent with that of Slater was obtained in a study made by Berkowitz, in which members of the groups showed more disagreement in solving logical problems in larger rather than in smaller groups [6].

The span of control has been a subject of much controversy. In general, theorists have found several factors influencing the selection of the proper span of control for any given situation. Moreover, it could be said that the great majority of authors refer generally to the same factors in their findings. Therefore, even though some controversy is present with regard to research in this area, span of control is definitely a major factor in organization design, and its selection influences the overall performance of an organization.

Span of control no longer appears to be isolated as a theme of study. The systems approach to the study of organizations is becoming a reality in this respect. Span of control plays a very important role in the present study since it is expected to influence the performance of the organization as a communication queueing system. The reason for this influence is that span of control determines the number of formal communication channels connecting each individual to the remainder of the organization.

Communications Flow

Communication, as noted earlier, is a prime factor in the performance of an organization. For a communication process to exist, there must be senders, receivers, and channels for conveying information. Communication could be thought of as the linkage element between all types of functions carried out within the organization.

It has been stated that the process of communication is effective only when the sender conveys a meaningful message which in turn causes the receiver to react in the manner intended. According to Zeyher [63], some of the factors influencing communication are:

1. The functional relationship between the sender and the receiver.
2. The positional relationship between the sender and the receiver.
3. The group-membership relationship.

4. Time, differences in hierarchy and prior environment.

5. Differences in formal education.

6. Past experience.

7. Emotions, and

8, Differences in vocabulary.

Chester I. Barnard, a representative figure of the traditional school, suggests seven conditions that he considers necessary for effective organizational communication [5]:

1. Executives must establish official channels of communication.

2. Every employee must report to a superior.

3. Formal lines of communication must be as short as possible.

4. Employees should use the entire channel of communication. (A communication should pass through every official level of an organization. However, in large organizations this procedure is likely to slow operations to such an extent that workers create informal channels of communication.)

5. All workers in the official network of communication must be competent.

6. Alternative official channels of communication must be established to reduce delays in the flow of information.

7. Standards must exist to authenticate information.

Recently, James A. Gazell made an analysis of Barnard's contribution in this field and argued that authority-flow theorists have recognized increasingly that this subject matter is more complex than the traditionalists and Barnard himself had thought [21]. Some attempts have been made to develop models capable of handling problems related to information processing activities. Decision processes have also been involved in the analysis of information and communication activities. In 1970 Thomas P. Ference published an article in an attempt to provide a testable framework for the empirical analysis of the decision process in organizations [20]. Ference's model is based on the information processing activities of the individual members of a communications network. The model describes the problem-solving process as a sequence of five stages: problem recognition; identification procedures; information acquisition and integration; definition of constraint set; and comparison and adaptation. This model is based on concepts of systems theory, an approach which is becoming predominant in this area.

The way communications are handled within an organization creates a communication environment characteristic of every organization. This so-called communication environment affects, according to Conrath, the organization's structure [14]. Even though no cohesive literature exists on the subject, Conrath supports his presumption of the existence of a relationship between an organization's communications environment and its structure by citing a reference by Chester Barnard who stated in his book [22, p. 91]: "In an exhaustive theory of organization, communication would occupy a central place because the structure, extensiveness and scope of the organization are almost entirely determined by communication techniques."

Conrath [14] performed an empirical study of communication content of relationships between persons located at one plant. His report focused on the structural properties of communications behavior. Some of the most important results of this study were that face-to-face communication was used far more often than other modes for interaction between persons located near (less than 200 feet) each other, and that written communication was inversely associated with distance (i.e., more used as distance increased). However, Conrath concludes that more extensive research is necessary to fully appreciate the role of organizational communications and the influence of the communications environment.

An important concept in this regard is discussed by Mintzberg [41] as he presents a study of the activities performed by all managers in an organization. He divides the manager's working roles into three groups: (1) interpersonal roles; (2) informational roles; and (3) decisional roles. According to Mintzberg, the manager can be conceived as the "nerve center" of his organization. The manager has formal access to every subordinate in his organization and also to a variety of outsiders; this makes him the organization's information generalist. He performs also the role of disseminator by transmitting some of his internal and external information to subordinates. In summary, Mintzberg expresses that the manager's work is essentially that of communication.

A somewhat different perspective on the communication process is given by Lee and Zwerman as they consider horizontal and diagonal communications in organizations [36]. They note that getting the right information to the right place at the right time can be a serious problem, particularly if information must move horizontally or diagonally. According to them, success in organizations today is dependent upon effective horizontal and diagonal communication systems as well as the traditional vertical communications. A good combination of these types of communication is always necessary. For instance, some decisions requiring prompt action should not rely upon the vertical communication system because of its inherent slowness and cost. Likewise, while there may well be clear advantages to specialization and departmentalization in organizations, a natural consequence is a reduction of information exchange. Therefore, a proper combination of types of communication as well as the type of structure in terms of specialization must be obtained in order to generate better results from all activities performed as part of the organizational function.

Successful communication depends on many factors, and almost any serious effort to improve it should have beneficial results. Brown [8] presents a very interesting point of view to what he calls "barriers to successful communication." In his article, Brown divides the barriers into two major areas: macro and microbarriers. Macrobarriers are considered by him as parts of the larger environment of an organization, whereas the microbarriers are the specific ones present in the individuals themselves. However, both influence the communication process. Macro and microbarriers can be dealt with, and the effective communicator should understand the limitations they may impose and, at the same time, be prepared to do what the situation may require to improve communication. Brown states that some people are better communicators than others; and that communication effectiveness is a function of the situation. A good communication system should take into account all these factors to come up with the best design, given the conditions and resources that are present at a given moment.

Another interesting standpoint from which to analyze communications is presented by Connolly [13]. He concentrates on decision-making processes and judgemental activities based on information. In his article, Connolly presents two approaches to organizational research with the intention of making organizational decision making more understandable by focusing on "flows and transformations of information associated with the decision process." The individual in the organization is viewed as an information-processing machine, performing activities of receiving, storing, and processing information as part of the decision making process carried out within an organization. Some approaches to interrelate the information-processing with the decision-making activities are suggested. The analysis is extended to two-person interactions, and then to multi-person processes. Here the focus is at a macro level, considering the environment of the organization as a communication net. A final remark states the purpose of the article as a stimulation for new empirical research.

In summary, the flow of communications within the organization (horizontal, vertical, or diagonal) has a significant impact upon the effectiveness of the activities performed by the organization. An appropriate combination of these types of communication is always necessary, and it depends on the particular characteristics of every organization.

The way that communications are handled creates a communication environment characteristic of every organization. A critical aspect of that environment is the queueing performance of the communication system in terms of its ability to handle the required flow of communications. Clearly, the queueing performance will be partially determined by the formal structure of the organization.

Organizational Analysis

Articles published on organizational analysis range in complexity from those merely presenting points of view to those developing complicated models to analyze various factors involved in the organizational context. Much of the research in this area has involved surveys of successful organizations to try to synthesize their characteristics as they relate to different conditions.

Points of view concerning organizational effectiveness and structural authority are presented by authors such as Etzioni [18], who describes the three expectations found in a traditional organization with regard to the organizational structure. He considers that (1) managers have the major (line) authority, whereas experts deal with secondary activities and therefore have only limited (staff) authority; (2) institutional heads have to be management-oriented because their role is one of system integration; and (3) organizational goals can be maintained more effectively in organizations with one center of authority (monocratic organizations). Etzioni also states that these concepts do not apply for professional organizations (schools, universities, etc.) since their major role is to achieve expertness; the concept, according to him must be reversed since staff "experts" are carrying out the major goal activity while "line" plays a service role.

Max Weber [59] summarized the characteristics of a bureaucratic organization in six conditions: (1) well-defined hierarchy of authority; (2) division of labor based upon functional specialization; (3) system of rules covering the rights and duties of positional incumbents; (4) system procedures for dealing with work situations; (5)

impersonality of interpersonal relationships; (6) selection for employment and promotion based upon technical competence. Hall [25] utilizes the concepts of bureaucratic organizations and applies them to the analysis of intraorganizational structures. Hall classifies the tasks encountered in an organization into two types: (1) Type I tasks: uniform, easily routinized tasks; and (2) Type II tasks: social or creative skills (research, sales, design, advertising). These Type II tasks are not covered by the bureaucratic model; they are better handled by more organic structures. He argues that organizations requiring the Type II skills would exhibit the bureaucratic dimensions to a lesser degree, whereas those which demand traditional Type I skills would exhibit such dimensions to a higher degree. According to the bureaucratic model, different types of behavior and interpersonal relationships are expected at different hierarchical levels and these differences appear to influence the structure.

An important study in this area was conducted by Woodward and involved a detailed analysis of 100 manufacturing firms in southeast England [62]. This study reports some interesting results related to span of control as a function of production technology. To perform the survey, the firms were categorized according to their level of technology into three types: (1) unit production: firms related to the production of small batches or simple units to consumers' orders or technically complex units; (2) mass production: the assembly-line type of firm; and (3) process production: firms involved in the production of chemicals in batches or continuous flow production of liquids, gases and solid shapes. According to Woodward's classification, the lowest level of technology is assigned to unit production type of companies, the intermediate level to mass production, and the most technological to those related to process production. The most important conclusions obtained by the survey were the following:

1. Levels of authority increased with technical complexity.
2. Number of managers as compared to total personnel increased with technical complexity.
3. Labor costs decreased with technical complexity.
4. Span of control of first-level supervisor increased from unit to mass and then decreased from mass to process production.

These results tend to stress the linkage between technology and the organizational characteristics. Furthermore, it can be said that not only is the system of production an important variable in the determination of organizational structures, but also that one particular form of organization was more appropriate to a particular system of production. Another important result is that successful firms of the large batch production type tended to have mechanistic management systems, whereas successful firms outside this range tended to have organic systems.

Since the publication of Woodward's book, three empirical projects which investigated a possible relationship between a measure of technology and a measure of social structure have been reported. The results are mixed. Harvey [28] found a very strong relationship between technology and program specification in 43 industrial organizations. Technology was measured as a dimension ranging from technical specificity to technical diffuseness, and program specification was a measure of the extent to which organizational communication and interaction patterns are predetermined and predictable. Hage and Aiken [24] conducted a study of 16 health and welfare organizations and found a negative correlation between the degree of routiness of the work and the degree of participation in organizational decisions. The negative correlation indicates that the more routine in the work, the less broadly based is participation in the decision making. A third study [30] made in 1969 reported no statistically significant relationships in 31 British manufacturing organizations between a measure of technology (largely the degree of automation of the work) and various measures of structure that might well figure as components in a mechanistic-organic typology.

Since 1970, modelling procedures have been adopted as a method for analyzing and designing organizational structures. Some of the models developed concentrate on certain relationships between parameters and characteristics of the structure. Klatzky [34] developed two models to examine the relationship between size of organizations and the percentage of staff personnel. The first is an interaction model in which, according to previous research and theory [39] [29], the effect of size is dependent on the level of functional differentiation or complexity, and such dependency or relationship does not appear to be linear. The second model, which is rather simple as compared to the first one, is a logarithmic model in which size decreases the staff component at a decreasing rate.

An example of how techniques used in different areas can be adapted for organizational analysis and planning is given by Muther and DeMoor

[43]. They made a very interesting adaptation of a plant layout procedure to the field of organizational analysis [42]. The recommended steps are: (1) establish a list of all the functions or activities; (2) list the functions or activities on a relationship chart and relate each activity to every other activity by an "importance of relationship" rating; (3) diagram the functions or activities, starting with those which should be the most related to each other and progressively relating the others by connecting them with four, three, two or one line according to the importance of their relation; (4) develop clusters of activities which logically fit together; (5) review the proposed clusters and refine any apparently misrated relationship, developing agreement on those functions which should be grouped together.

Williamson [61], an economist, presented an idea for dealing with hierarchies based on "control-loss". Williamson's model was based on the usual image of the organization as a tree. Each boss has several subordinates whose number constitutes his span of control. Actions taken to achieve goals are generated at the top of the organization and executed at the bottom. In between there are several levels of hierarchy. At each level, bosses give orders to subordinates which represent orders that they (the bosses) have in turn received from above. But at each level, according to Williamson, there is some "control-loss". Orders are misinterpreted and part of the original intention is lost. The total cumulated control-loss emerges at the bottom of the hierarchy as the proportion of production workers' time that does not further organization goals. In Williamson's model, wage costs are calculated by assuming that wages of superiors are some ratio of the wages of subordinates and that this ratio remains roughly constant at the different levels. He was therefore able to estimate the optimal size of an organization on the basis of a relatively small number of parameters. He found, for instance, that using a value of .90 for interlevel control and assuming average span of control between five and ten produced estimates of between four and seven for the optimal number of levels in the hierarchy, depending on the values chosen for the other parameters. Basically, Williamson's model consists of developing a net-revenue equation based on wages, costs of output, span of control, number of levels in the hierarchy, price of output and interlevel control. Then differentiating the equation and setting it equal to zero, an equation of optimal levels in the hierarchy is obtained.

Williamson's findings, however, make it difficult to explain empirical studies reporting ten or more levels of hierarchy [5] [62]. A more fundamental weakness of the model was the extent to which it makes organizational size dependent on the degree of interlevel control.

A very recent article by Waller [58] presents an exposition of how hierarchical structures are synthesized in an algorithmic manner. Waller uses the concept of matrices to construct what he calls a "reachability matrix", meaning the set of elements (subordinates) that reach a superior. The technique consists of finding reachability conditions starting from the top level hierarchy until all elements of the reachability matrix have been covered.

Organizational analysis has been approached from several standpoints. The results obtained by means of surveys provide a framework for a new approach to the study of this field. The insights gained by studying the linkages between factors influencing the organization (i.e., technology, type of tasks performed, etc.) and organizational characteristics provide a basis for developing modelling procedures as a method of analysis.

A more formal treatment of organizational structures is being adopted. Models are being developed to test the consequences of changes in different factors related with organizational design. The most convenient method for dealing with this field is still a matter of discussion and subject to more research. Nevertheless, the modelling methodology that has been developed in recent years is influencing greatly the study of organizations.

This part of the literature survey attempts to provide a background of the different approaches that have been used previously to organizational analysis. It pinpoints the recent trend toward modelling as a very useful technique in the study of this field. The present study also uses a modelling approach and represents, therefore, a systems theory approach.

Systems Theory and Its Contribution to Organizational Analysis

The organization can be considered as part of an environment which it influences and in turn is influenced by. As Tersine and Jones state [52, p. 32], "it is a man-made system of interrelated parts working in conjunction with each other to accomplish goals."

According to Coleman and Palmer, practicing managers and academicians have recognized recently the contribution of systems theory to the study of organizations. Organization theorists, say Coleman and Palmer, have turned their attention to systems theory for two main reasons [12, p. 78]: "First, the idea was new and its potentialities were there to be explored; second, existing approaches to organizations were showing signs of wear and deterioration."

It could be said that until recently there were two major approaches to the analysis of organizations. The older, which was based upon Frederick Taylor, Max Weber, and others, concentrated on structural properties, giving as a result theories of bureaucracy and the development of cornerstone principles in management. A later approach tended to emphasize the human element in the organization and led to the development of behavioral theories. However, in the opinion of Coleman and Palmer, both approaches turned out to be inadequate and this was in time recognized by analysts. The structural approach simply overlooked too many human realities covered by the human approach. Likewise this last approach lacked a verification of its core assumptions about human behavior supported by empirical research [60] [50]. Due to these problems, analysts are now developing the systems theory framework.

Organizational systems consist of sets of people, objects (such as equipment) and activities that are related to one another and can be distinguished from other sets. Coleman and Palmer comment [12, p. 78]:

> Most systems theorists conceive of the organization as a complex input-throughput-output system. The organization is separated from its environment by a permeable boundary. Through this boundary transactions occur which enable the organization to secure human, financial, and material inputs. Within organization boundaries, a number of interacting subsystems transform these inputs into a final product suitable to the environment. Output passes through the organization's boundaries reactivating the input-throughput-output cycle.

Chris Argyris has identified the major subsystems within an organization as those dealing with workflow, authority, reward, penalty, perpetuation, communication, and identification [2]. Argyris concentrated mostly on behavioral considerations.

The important concept here is that the system theorist analyzes the interaction and relationship between subsystems within the organization, as well as between the organization and its environment.

Several examples of studies that utilized a systems approach to analyze organizations can be given. Two which concentrate mostly on the subsystems are those of Chapple and Sayles in which the company under study is organized around functional specialities [11], and Rice and Bishoprick in which the organization is considered as a collection of modules, each being autonomous and with a specific output [44]. Though the organizational environment was taken into account in these studies, it was not fully analyzed.

Other researchers have concentrated on the organization-environment relationship. Burns and Stalker examined management practices in 20 British organizations from the organization environment point of view [10]. Their conclusions, in agreement with classical principles, indicate that organizations confronting a stable environment tend to develop mechanistic approaches to management, whereas organizations facing less stable environments tended to utilize more organic managerial practices to be able to handle the changes.

Later, a study by Lawrence and Lorsch extended these concepts to provide an approach to organization design that incorporates environmental considerations [35]. The study is highly complex, but three conclusions are obtained. First, different environments require different types of structures. Second, some integrative devices are necessary for organizational effectiveness. Third, the most successful organizations analyzed in the study had both high differentiation and high integration. Differentiation is considered in the study under two dimensions: structural and psychological. In the structural sense, it means an elaborate segmentation of jobs, tasks or departments. In the psychological area it means that its members have a wide range of perceptions of reality. Integration refers to the degree of collaboration between organizational subsystems. Lorsch, in a later work, applied the concepts of differentiation/integration in the design of organizations [37].

In the opinion of Tersine and Jones, no single model is appropriate in depicting the multiplicity of relationships normally encountered in an organization [52]. These authors consider it useful to classify the organization's environment into micro, linking, and macro-environments. The micro-environment, according to them, represents the internal activities of the organization itself; the linking environment represents the interface between internal and external environments, and the macro-environment is considered to be the environment external to the organization. In their article, Tersine and Jones discuss four models that integrate the three environments as a whole standpoint to approach organization design. The four models are called "Systemic Environmental Model", "Systemic Planning Model", "Systemic Functional Model", and "Systemic Operational Model". According to the authors, the models comprise all relationships that may be encountered in an organization.

Fremont E. Kast and James E. Rosenzweig make a very extensive analysis of systems theory. These authors bring together concepts about the systems approach to organization design discussed by several theorists [9] [38], and provide a very good definition of the contingency view of organizations [33, p. 460]:

> The contingency view of organizations and their management suggests that an organization is a system composed of subsystems and delineated by identifiable boundaries from its environmental suprasystem. The contingency view seeks to understand the interrelationships within and among subsystems as well as between the organization and its environment and to define patterns or relationships or configurations of variables. It emphasizes the multivariate nature of organizations and attempts to understand how organizations operate under varying conditions and in specific circumstances. Contingency views are ultimately directed toward suggesting organizational designs and managerial systems most appropriate for specific situations.

Using the contingency theory, Shetty and Carlisle developed a model that views organizations as a product of many forces in the managers, in the technology and environment, and in the subordinates. The theory supports the idea that there is no best way in which to organize, but rather, that an effective organization is designed according to its managers, market environment, technology and subordinates. Or stating it in the terms used by Coleman and Palmer [12, p. 81]: "A system theory does not provide a 'one best way' to design organizations. Rather it amplifies and extends our understanding of the factors that should be considered when a design problem is confronted."

Summary

The literature survey has shown that a variety of factors must be taken into account when designing an organization. There are also a variety of ways to approach the problem of organizational analysis.

This study is developed with the purpose of simulating and analyzing a hypothetical organization from the standpoint of communication queueing systems. Theory and research related to span of control and communications, therefore, are of primary importance. As these two segments of the literature were examined a tendency toward systems theory as a technique for organizational analysis was noticed. Finally, as the last part of the literature survey, it was considered important to review what has been done with systems theory in the area of organizations. The reasons for the importance of the systems theory literature are the recognized tendency toward the analysis of organizations from this standpoint and the fact that this study involves a systems approach to organizational analysis.

CHAPTER III

METHODOLOGY, SCOPE, AND LIMITATIONS

General Approach

In Chapter I it was mentioned that a hypothetical organization was used as the basis of this study. The hypothetical organization contains 16 homogeneous functional positions in the lowest organizational level or echelon. As the organizational structures were changed, the 16 positions in the lowest level were maintained. This gave a basis for comparison, since all organizational structures contained those 16 lower level positions. Furthermore, the performance of these positions was one of the key elements for comparing structural designs.

For the proposed organization, there are eight different symmetrical management structures that can be developed in pyramid fashion above the lowest level. These different possibilities are obtained by making all possible combinations of span of control, increasing the number of managers as well as the number of organizational levels as the span of control decreases. The eight structures are shown in Figure 3-1 and their characteristics are summarized in Table 3-1. A separate simulation model was developed for each of these eight structures.

In any organization a communication process is carried out as a natural function. The communication process is done by means of orders or messages sent from one position to another and sometimes passing through several others within the organization. Individual messages were simulated or modeled as GPSS "transactions". Each position in the

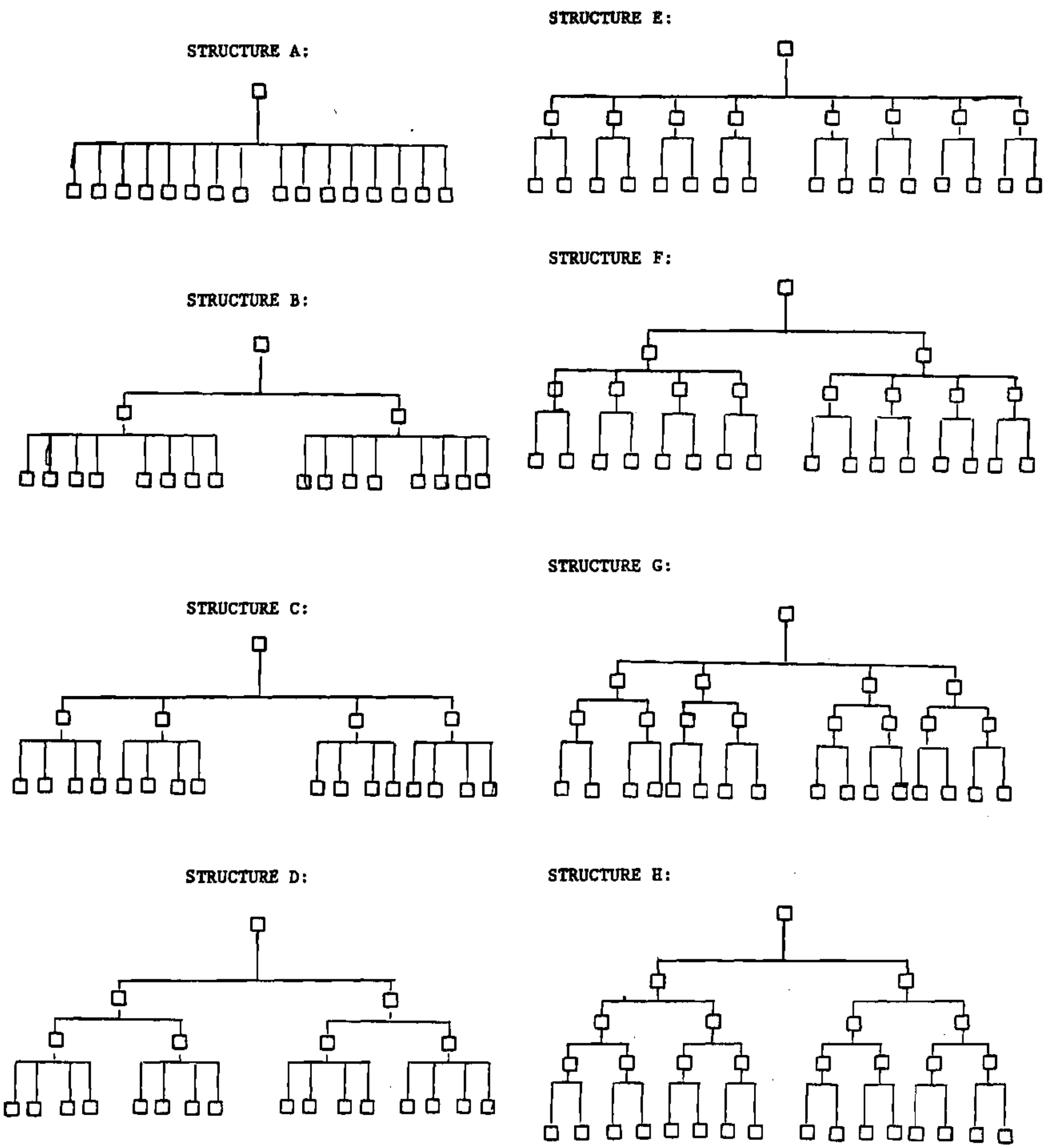


Figure 3-1. Alternative Structures

Table 3-1. Summary of Structure Characteristics

STRUCTURE	TOTAL NUMBER OF MANAGERS	TOTAL NUMBER OF ORGANIZATIONAL LEVELS	Spans of Control by Management Level: Top Level	2nd Level	3rd Level	4th Level
A	1	2	16	--	--	--
B	3	3	2	8	--	--
C	5	3	4	4	--	--
D	7	4	2	2	4	--
E	9	3	8	2	--	--
F	11	4	2	4	2	--
G	13	4	4	2	2	--
H	15	5	2	2	2	2

organization structure was modeled as a "facility" that "processes" messages one at a time.

Because of the problem of finding appropriate conditions for interstructural comparisons, only those organizational positions that will be present in every simulation, no matter what the overall structure may be, were allowed to "generate" messages. Those positions happen to be the manager at the top level and the 16 positions at the lowest level. The other intermediate positions, which are the managers occupying positions at the second, third and fourth managerial levels, were only allowed to "process" and "transfer" the transactions received from other positions, and could not "generate" them. After a message had been processed within a given organizational position, it could be "terminated", or it could be "transferred" to another organizational position for further processing. The "terminate/transfer" decisions were determined stochastically within the models.

Four sets of communication parameters were used as alternative simulation run conditions. Table 3-2 shows the values for the parameters in each of the four sets.

Table 3-2. Communication Parameter Values

Run Condition	Average Inter-message Generation Time (min)	Average Message Processing Time (min)	Message Termination Probability
CASE 1	30 ± 15	10 ± 7	.50
CASE 2	20 ± 15	10 ± 7	.50
CASE 3	30 ± 15	15 ± 7	.50
CASE 4	30 ± 15	10 ± 7	.40

Messages were generated stochastically at a rate uniformly distributed over the range of the average plus or minus 15 minutes. For message processing the range varied from the average rate plus or minus seven minutes. (It is important at this point to note that all the figures used in the study were selected trying to represent possible realistic conditions, but they are not chosen to depict any particular real organization.)

Cases two, three and four each vary from the first case in that only one of the three parameters has been changed from its original value. In each case, the change increases the communication burden on the system. A simulation run was made for each of the eight organizational structures under each of the four run conditions, yielding a total of 32 runs. Absolute and relative changes in the performance of each structure under the various run conditions were analyzed.

The eight alternative organizational structures can be compared and evaluated in a number of ways. One obvious criterion is the relative cost of the management personnel required for each structure. In evaluating the actual performance of each structure as a communication queueing system, the criteria of interest in this study were:

1. The distribution of message throughput times; that is, the total lifetime of the message from generation to termination, including both processing and waiting time. The objective is to minimize the mean and variance of this distribution.

2. The distributions of message queue lengths and queue waiting times for each organizational position. Again the objective is minimization, plus the prevention of severe bottlenecks within the structure.

3. The utilization of each organizational position measured as the percentage of time that the position is busy processing messages. It is recognized that, in reality, the

organizational positions will be involved in other activities as well. However, many of the other activities can be visualized as communication processing (decision making, planning, etc.) in terms of the time required. Here, the objective would be fairly high and uniform utilizations for all positions.

Simplifying Assumptions

To limit the complexity of the models and to enhance the comparability of simulation results obtained for the various organization structures, the following assumptions were made:

1. Organizational positions process one message at a time on a first-come-first-served basis. All messages have the same priority regardless of whether it was generated by the manager at the top level or by one of the 16 lower level positions. In real organizations, messages coming from higher level positions sometimes have a higher priority than others. Therefore, this assumption detracts somewhat from the realism of the model.

2. Once begun, the processing of a given message within a given position continues uninterrupted until completed. Here again, a real situation is not perfectly represented; nevertheless, this assumption provides a fair basis for comparison in terms of message-throughput times.

3. Messages are generated only by positions at the top level and bottom level of each organizational structure. Positions at the intermediate levels only process messages that are transferred to them from other positions. This assumption is not as unrealistic as it may first appear to be if it is taken into account that much of the message processing at middle levels can be visualized as ultimately originating as a communication from above or below.

4. The distribution of message processing times is the same for all organizational positions regardless of their level in the structure. The message inter-generation time distributions are also the same for all positions that are allowed to generate messages. In reality, the rate of generation might be expected to be a function of span of control, or other factors.

5. The probability that a given message will be terminated after processing by a given organizational position is the same for all positions. The probability of termination, however, might well be expected in reality to be

> less for middle level managers than for top and bottom levels of the organization. Messages that are not terminated after processing are transferred to one and only one of the positions that are formally connected to the transferring position in an immediate superior, subordinate, or horizontal relationship. In each case, all eligible destination positions have an equal probability of being selected. The possibility of "diagonal" communications is ignored.

These assumptions represent limitations in the scope of the study only and should not be viewed as limitations of the modelling or simulation methodology. In fact, the GPSS language could easily facilitate the relaxation of any of the assumptions.

Modelling Methodology

Selection of Language

The widespread use of digital computers for carrying out simulation studies has led to the development of many special purpose programming languages that greatly facilitate the development of simulation models. When using simulation techniques, a clear distinction must be made between continuous and discrete models. Our case is one of a discrete model. The system entities are uniquely identified and status changes occur instantaneously rather than continuously.

The computer language General Purpose Simulation System or GPSS has been specifically designed for applications to discrete system simulation. In particular the latest version of GPSS, called GPSS V, includes some advantages over earlier versions [22]. GPSS V as well as most other discrete simulation programming systems, provides several independent random number generators and can arrange for any of them to produce a different sequence of random numbers by changing a seed value. It allows the use of a "clock time" which records the passage of time with next-event updates, making possible the simulation of long periods of model time in relatively little computer time. It also provides automatic statistical analysis and reporting.

The structure of GPSS in particular makes this simulation language very suitable for analyzing queueing systems. Since the point of view from which the organizational structures will be analyzed is that of communication queueing systems, GPSS V fits perfectly the needs of this study.

Some GPSS Concepts

In GPSS the simulation of any system is made by means of "block types". Each block type has a name and represents individual actions that occur in the system as "transactions" move through the system. A summary of terms, concepts and block types which are used in the simulation programs for this particular study is given in Table 3-3. The positions or people in the organization were treated as "facilities". Some positions (manager at the top, and operatives at the bottom level) were allowed to "generate" messages as well as processing and transferring them. The positions at the levels between the top and bottom, however, were only allowed to process and transfer the messages received from other positions in the organization. The two blocks associated with a facility are "seize" and "release". They represent the starting and finishing of the processing of a "transaction" respectively. As the computer executes these blocks (i.e., causes a message to pass through them), it will automatically calculate the number of messages that have entered the "facility", the average time per transaction, and percentage utilization of each facility or person, as well as other

Table 3-3. GPSS Terms Used and Their Meaning for a Communication Queueing System

GPSS	MEANING
TRANSACTION	Communication or message
FACILITY	Person or position within the organization
QUEUE	Group of messages waiting in line to be processed by a particular position
GENERATE BLOCK	Creates messages
QUEUE BLOCK	Message enters queue to await processing by a given person
SEIZE BLOCK	Person begins processing a given message
DEPART BLOCK	Message leaves a queue to be processed
ADVANCE BLOCK	Determines duration of the processing time of a message by a given person
RELEASE BLOCK	Person finishes processing a message and is available to process the next one (if any) in the queue
TRANSFER BLOCK	Routes message to another person or to be terminated
TABULATE BLOCK	Records the total time that the transaction spent in the system
TERMINATE BLOCK	Kills the message or communication; no further processing for that message

figures which are not of interest for our study.

A similar procedure is executed by the computer as transactions enter the two blocks related to queues, namely, "queue" and "depart". Here, the most relevant data generated by the computer are the average contents of each queue and the average time spent in the queue per transaction. Some other figures automatically calculated are the maximum and current contents of queues, and total entries.

The block type "tabulate" allows for the creation of tables which provide statistics concerning the throughput time of the "transactions". The mean and standard deviation of the time that the transactions spend in the system is obtained; and a table of the observed frequency of transactions falling within certain ranges of total throughput time is also given.

With all these concepts in mind it is now convenient to explain the modelling features of the simulations made for the study.

Modelling Features

As was mentioned previously, an organizational structure with 16 positions at its bottom level has been selected for the analysis. Starting from this basis, eight different structures can be developed according to span of control (see Figure 3-1). Some of them turn out to be more complex in terms of modelling than others; however, Structure B possesses all features or characteristics that other structures have, and presents a level of complexity which permits a relatively simple illustration of the basic modelling procedure.

Figure 3-2 illustrates the flow diagram followed for Structure B. The block type names are shown for the top manager only. Also, only the

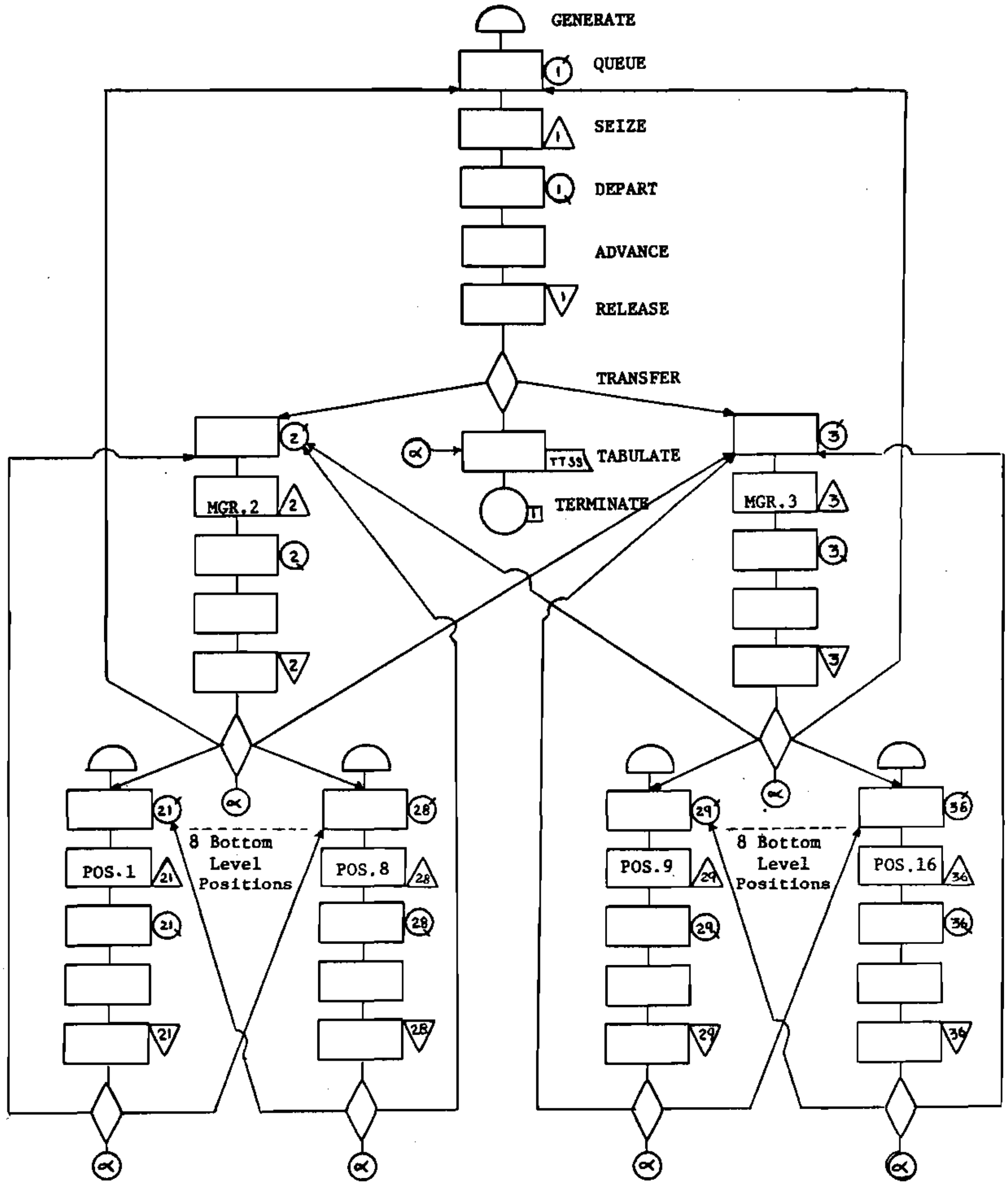


Figure 3-2. Flow Diagram for Structure B

first, eighth, ninth, and sixteenth bottom level positions are explicitly shown. If this figure is compared to the diagram of Structure B shown on Figure 3-1, it will be noticed that both figures follow the same overall shape or configuration. The computer program corresponding to Structure B (Case #1) is shown in the Appendix.

The computer programs are fairly repetitive. Every position performs the same operations, with the exception of the generating of messages. Once a message has arrived at a given organizational position, it enters a queue which will arrange messages to be processed on a first-in-first-out basis. Then, once the message reaches the front of the queue and the position is idle, the message enters the "seize" block, meaning that the position starts processing it. This, of course, imposes the necessity of passing through a "depart" block to indicate that the queue has been left. The "advance" block determines the processing time for the message on a stochastic basis. Once the transaction has been processed, it passes through a "release" block to indicate that the position is now free and ready to process the next message in the queue. Here, as was previously explained, transactions are either terminated or transferred to another stochastically chosen queue corresponding to a directly connected position.

Description of Run Conditions

Four runs were obtained for each organizational structure, each corresponding to a different set of communication parameter values (refer back to Table 3-2 for summary of values). The three parameters, average message generation rate, average message processing rate, and message termination probability were contained within the models in the "generate", "advance" and "transfer" blocks respectively. Therefore, the only difference between the four simulation runs for a given structure (in terms of the instructions given to the computer) were in the values assigned to the fields of these three block types. The flexibility of the "generate" and "advance" blocks in terms of the range of time values they can take is maintained throughout all simulations. That is, ranges of ±15 minutes and ±7 minutes are allowed for generation and processing times respectively.

In moving to more complex structures, the number of managerial positions is increased, going up to 15 managers for Structure H. Consequently, "functions" which delineate the transfer probabilities of messages between positions were revised, resulting in a different set of functions assigned to each organizational structure.

Finally, the simulations were run for 6000 transactions, and intermediate printouts were requested every 1000 transactions. In this way, it was possible to obtain data that indicated whether the system was reaching equilibrium or not. A system was considered to reach equilibrium if the mean message throughput time eventually leveled off as the number of messages terminated increased. This will be explained in more detail in the next chapter as the concept of equilibrium is analyzed.

CHAPTER IV

RESULTS

Review of Run Conditions

The four sets (or cases) of run parameters were presented in Chapter III, and are summarized again in Table 4-1 for easy reference. It is worthwhile to review these run parameters briefly prior to the presentation of the simulation results.

Table 4-1. Summary of Run Parameters

	CASE #1	CASE #2	CASE #3	CASE #4
Average message inter-generation time ($1/\lambda$)	30 min.	20 min.	30 min.	30 min.
Average message processing time ($1/\mu$)	10 min.	10 min.	15 min.	10 min.
Message termination probability (P_t)	.50	.50	.50	.40

Note again that in each of Cases #2, #3, and #4, only one parameter has been changed from the Case #1 conditions. Furthermore, the changes are always such that they increase the communication burden on the organization.

The parameter changes made for Cases #2 and #3 cause the ratio:

$$\frac{\text{AVERAGE MESSAGE INTER-GENERATION TIME}}{\text{AVERAGE MESSAGE PROCESSING TIME}} = \frac{(1/\lambda)}{(1/\mu)} = \frac{\mu}{\lambda}$$

to decrease from 3/1 (for Case #1) to the value of 2/1. Thus, Cases #2 and #3 are somewhat comparable in their relationships to Case #1.

Case #4, however, is not directly comparable to Cases #2 and #3, in terms of the extent to which the decrease in message termination probability from .50 to .40 increases the communication burden over Case #1.

Equilibrium of Runs

As was explained at the end of the last chapter, each simulation was run for 6000 transactions. Some structures,due to their broader span of control, may turn out to be less efficient in handling the transactions than others. For this reason, it was expected that, in some cases, equilibrium would not be reached. The parameter that was used as a measure of the degree of equilibrium reached by any given structure is the "mean throughput time". It describes the mean time taken for any message to be terminated since it entered the system at its generation stage.

Therefore, to test for equilibrium of runs, the mean message throughput time was graphed as a function of the number of messages terminated (it will be recalled that a printout was requested every 1000 transactions for this purpose). The four alternative run conditions were plotted for each of the eight structures. Figures 4-1 through 4-5 show the behavior of these graphs. It is convenient to discuss some important aspects that can be realized by analyzing the graphs:

1. Case #3 constitutes the worst set of conditions for every structure in terms of the time needed to process transactions.

2. As would be expected based on the run conditions, Case #1

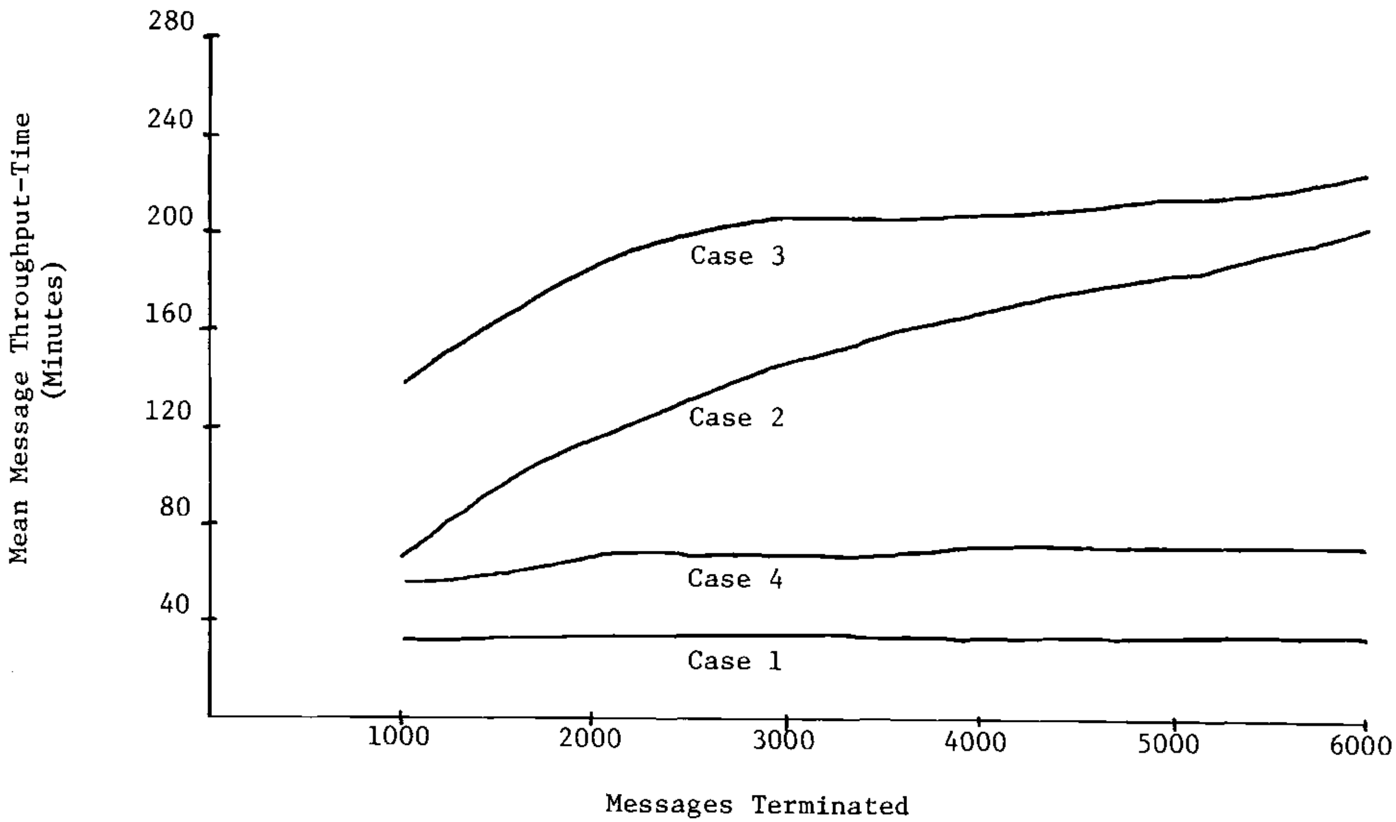


Figure 4-1. Equilibrium Graph for Structure A

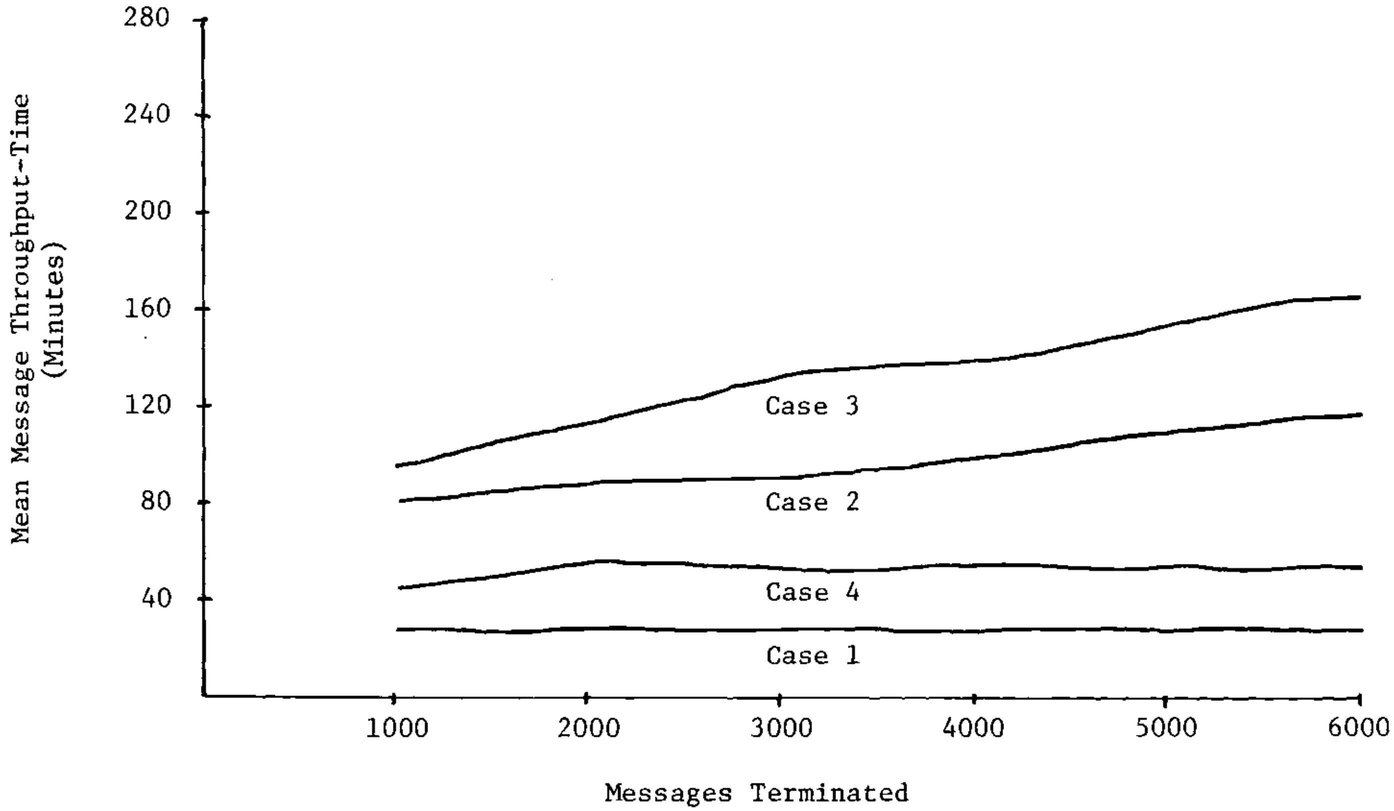
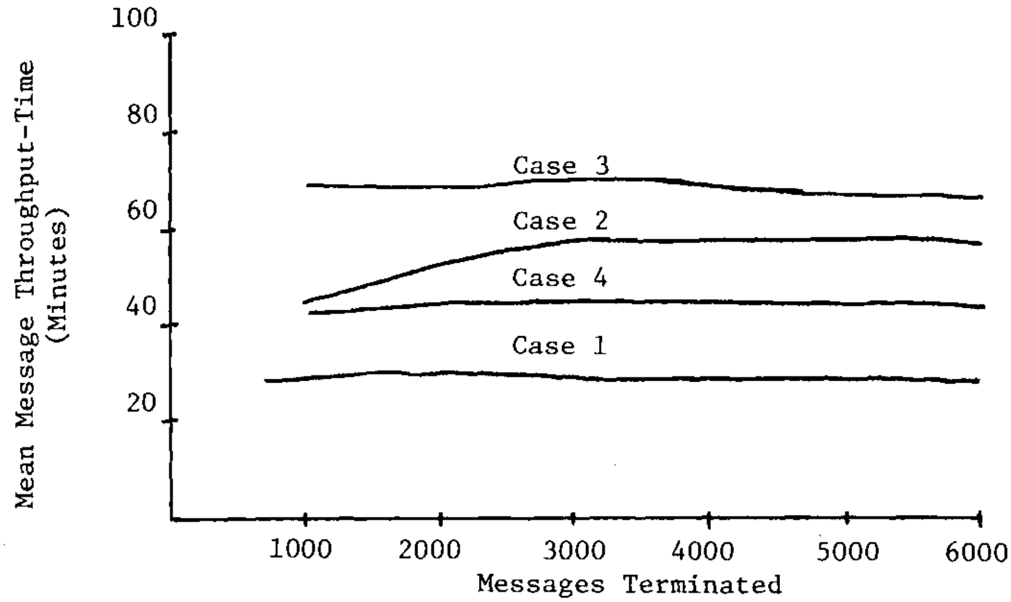
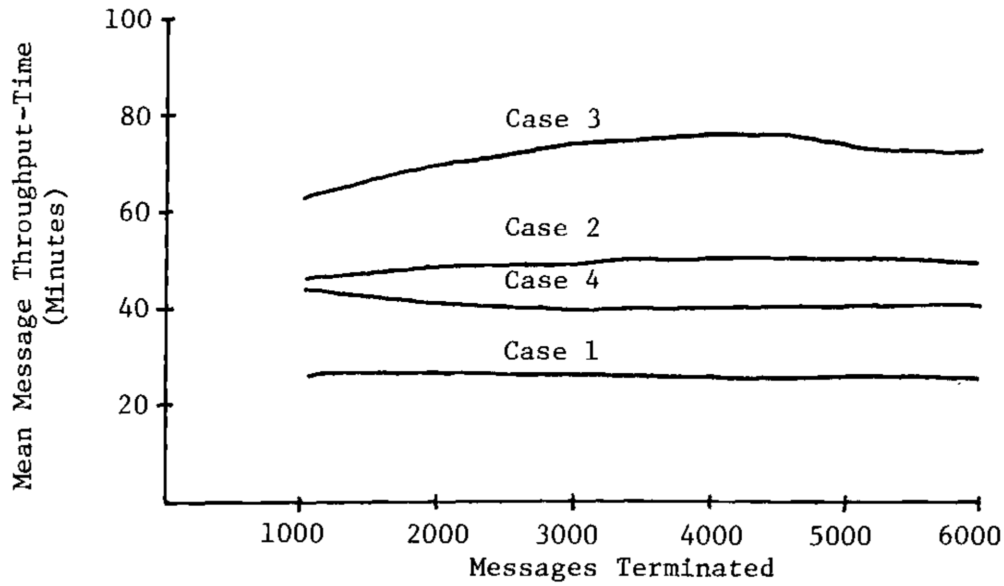


Figure 4-2. Equilibrium Graph for Structure B

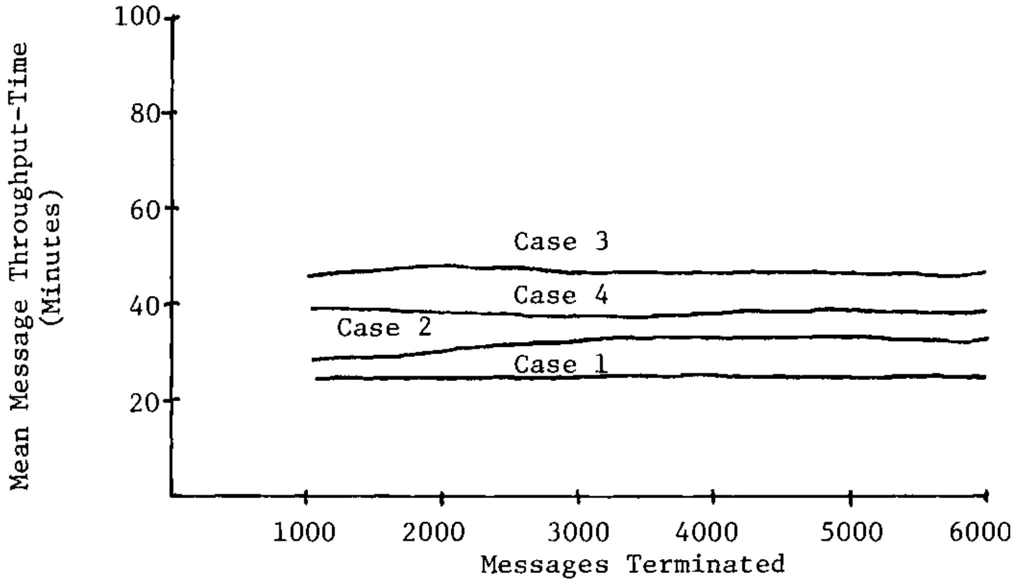


STRUCTURE C

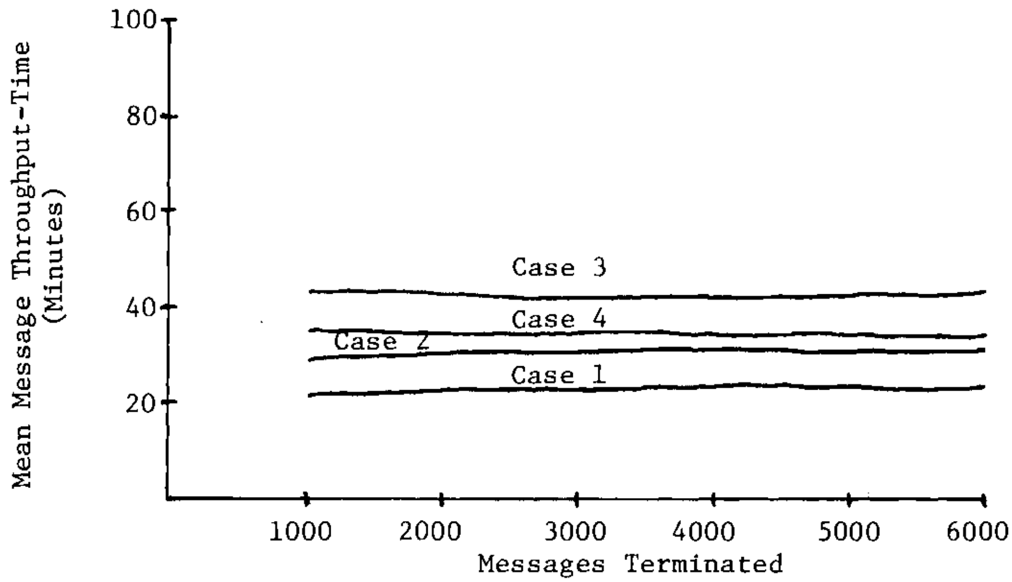


STRUCTURE D

Figure 4-3. Equilibrium Graph for Structures C and D

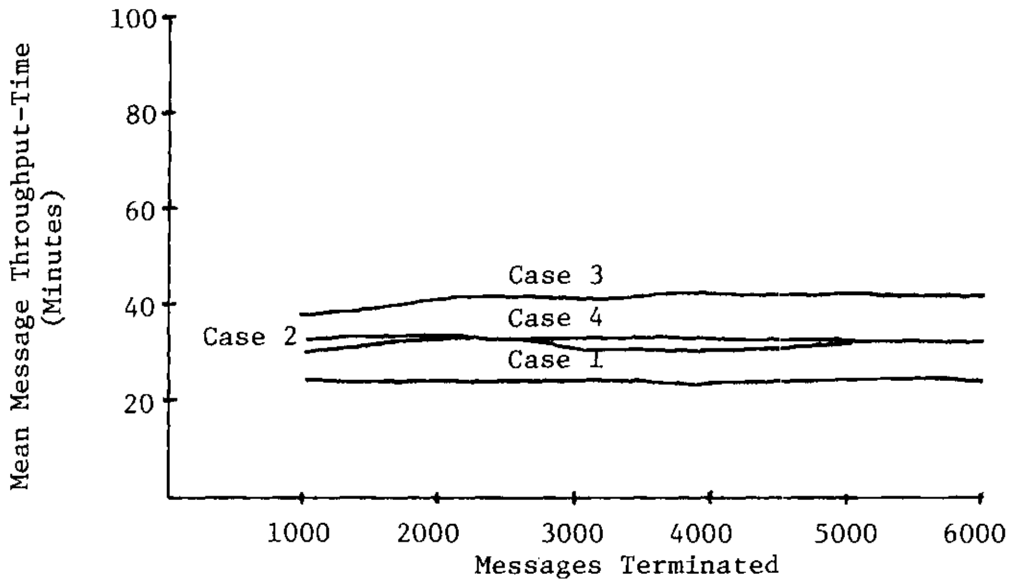


STRUCTURE E

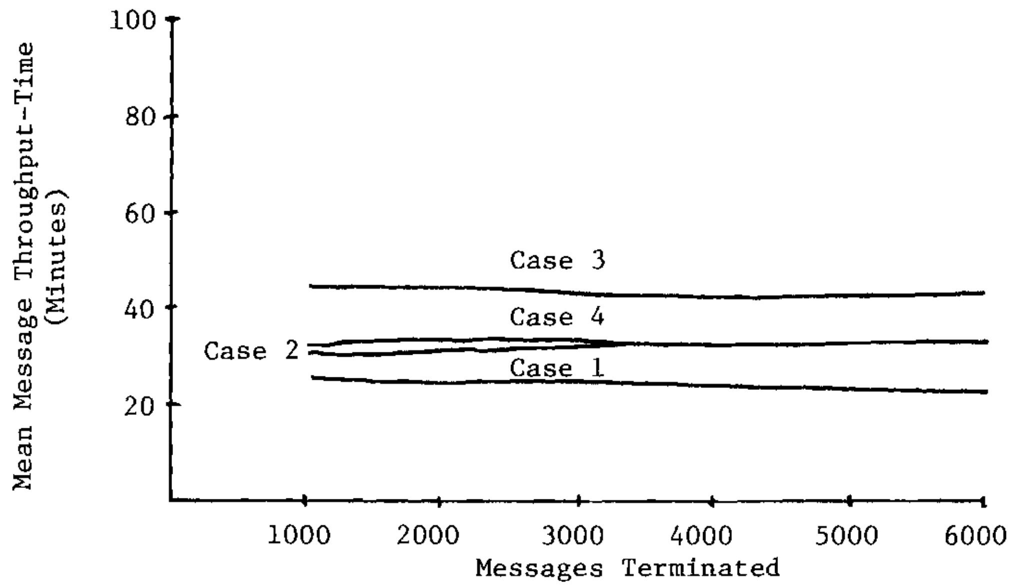


STRUCTURE F

Figure 4-4. Equilibrium Graph for Structures E and F



STRUCTURE G



STRUCTURE H

Figure 4-5. Equilibrium Graphs for Structures G and H is consistently the one that takes the least time to process transactions, and it always reaches equilibrium within the first 1000 transactions.

3. Structures A and B result in the largest mean throughput times, and constitute the only structures for which a case does not reach equilibrium after 6000 transactions. Specifically, the mean throughput times for Cases #2 and #3 for both structures are still increasing after 6000 transactions. Indeed, we cannot say with certainty whether these runs would have ever reached equilibrium. All other structures reach equilibrium under the conditions of every case.

4. Structures A, B, C and D perform slightly better in Case #4 that in Case #2. However, the difference between them decreases as we pass from structure A to D (i.e., as the number of managers in the structure increases). Structures E, F, G and H perform slightly better in Case #2 than in Case #4.

5. Structures E, F, G and H perform very similarly for all cases. This suggests nine managerial positions as the limit after which increasing the number of managers would not increase effectiveness, but only the cost of maintaining a higher number of positions.

Message Throughput Times

Since Cases #1 and #3 were the least and most burdensome cases respectively in terms of mean message throughput times, it is convenient to make a more detailed analysis of the message throughput times obtained in these cases for each structure. Tables 4-2 and 4-3 summarize the distributions of message throughput times for Cases #1 and #3 respectively. Also included are the means and standard deviations (expressed in minutes) of all structures for both cases.

Taking first Case #1, it can be observed that the percentage of messages that were terminated in the range of zero to 60 minutes is large for all structures. This percentage generally increases, although there is little change in the percentage for structures E, F, G and H. Structures B and C are the only ones for which messages take more than

Table 4-2. Message Throughput-Time Distributions for Case #1

Upper Limit (Minutes)	Organizational Structures A	B	C	D	E	F	G	H
60	85.38	88.05	90.00	91.57	93.25	94.02	93.95	94.63*
120	12.67	10.77	8.87	7.88	6.48	5.62	5.70	5.00
180	1.70	1.11	1.05	0.50	0.27	0.32	0.28	0.33
240	0.25	0.05	0.07	0.05	----	0.05	0.07	0.03
300	----	0.02	0.02	----	----	----	----	----
Mean	33.17	30.16	28.22	26.55	24.21	23.88	24.06	23.50**
Standard Deviation	29.33	26.23	25.24	22.54	20.72	20.59	20.37	19.61

*Percentage of total transaction throughput-time for that structure.
**Minutes

Table 4-3. Message Throughput-Time Distributions for Case #3

Upper Limit (Minutes)	Organizational Structures A	B	C	D	E	F	G	H
60	20.47*	34.35	57.83	55.68	75.35	78.17	78.60	77.77
120	18.43	20.72	27.70	25.98	18.58	17.55	17.38	18.25
180	13.38	12.83	9.35	10.60	4.22	3.38	3.37	3.13
240	11.95	8.13	3.30	4.43	1.25	0.68	0.62	0.67
300	10.02	6.65	1.13	1.93	0.48	0.17	0.12	0.18
360	7.03	5.45	0.48	0.82	0.08	0.05	0.02	----
420	4.08	3.60	0.13	0.28	0.03	----	----	----
480	3.30	2.60	0.03	0.15	----	----	----	----
540	2.73	1.52	0.00	0.02	----	----	----	----
500	2.35	0.93	0.00	0.02	----	----	----	----
660	1.53	0.82	0.02	0.05	----	----	----	----
720	0.97	0.45	0.00	0.03	----	----	----	----
780	0.98	0.33	0.02	----	----	----	----	----
840	0.68	0.38	----	----	----	----	----	----
900	(2.08)**	(1.23)**	----	----	----	----	----	----
Mean	227.38	166.78	66.90	74.18	45.89	42.70	42.40	43.18
Standard Deviation	213.05	184.65	58.45	68.54	42.19	36.31	34.63	35.23

*Figures in percentages
**Distributions not available

240 minutes to be terminated. However, the percentage of messages falling in this range is extremely small for both cases. On the other hand, structure E has the smallest range of message throughput times among all structures, none exceeding 180 minutes. The mean and standard deviation generally decrease as the number of managers in the structure increases. One point however that should be stressed is that the marginal differences between both mean and standard deviations become extremely small as we pass from structure E to H; whereas to structures A to D the differences are more observable. This fact indicates that the parameter to evaluate between the last four structures (E to H) may well be based on cost since the gain in effectiveness from one structure to another could be considered negligible. Another point to be noted is that structure G yields a very slight increase in the value of the mean throughput time as compared to structure F.

Now turning the analysis to Case #3 shown on Table 4-3, it can be noticed that the throughput-time distributions are much more dispersed than the ones obtained for Case #1. Unfortunately, the complete distribution for structures A and B is not available due to the limits imposed in the "table block". However, this fact does not affect the analysis of the table, since the values of means and standard deviations are accurately recorded anyway. Under the conditions of this case the difference in performance between the first four structures (A,B,C and D), and the last four (E,F,G and H) becomes more dramatic. Structures A and B present throughput-time values that are not characteristic of a system performing its functions correctly. That is, such values indicate that structures A and B are incapable of handling the conditions prevailing for Case #3. If these represented real-world organizational situations, messages would probably be going unprocessed and communication delays would be becoming intolerable. Now, by looking at mean and standard deviation values it can be seen that structure D is less effective than structure H when compared to structure G. This is a somewhat different behavior than that observed for the same structures under Case #1.

In order to better observe the patterns of behavior characterizing Cases #1 and #3, the message throughput-time distributions for structures A and H were graphed in Figure 4-6. A general pattern is that for Case #3 the time for message termination is larger than for Case #1. Likewise, as was expressed (see Figures 4-1 and 4-2), structure A is incapable of handling the conditions presented under Case #3. Structure H, on the other hand, yields a pattern of behavior very similar under the two cases. This result tends to show that when the number of intermediate organizational positions is rather large, the system is more capable of handling extreme conditions.

In order to complement the analysis, a summary of means and standard deviations of message throughput-time distributions is given in Table 4-4. It includes data for the four cases under consideration. The results that have been discussed under this section can be observed by comparing these data on an inter-structural basis, and then across cases for any given structure.

Message Queues

When discussing queues, emphasis will be placed on two factors: (1) Message queue lengths; and (2) Queue waiting times. Though these

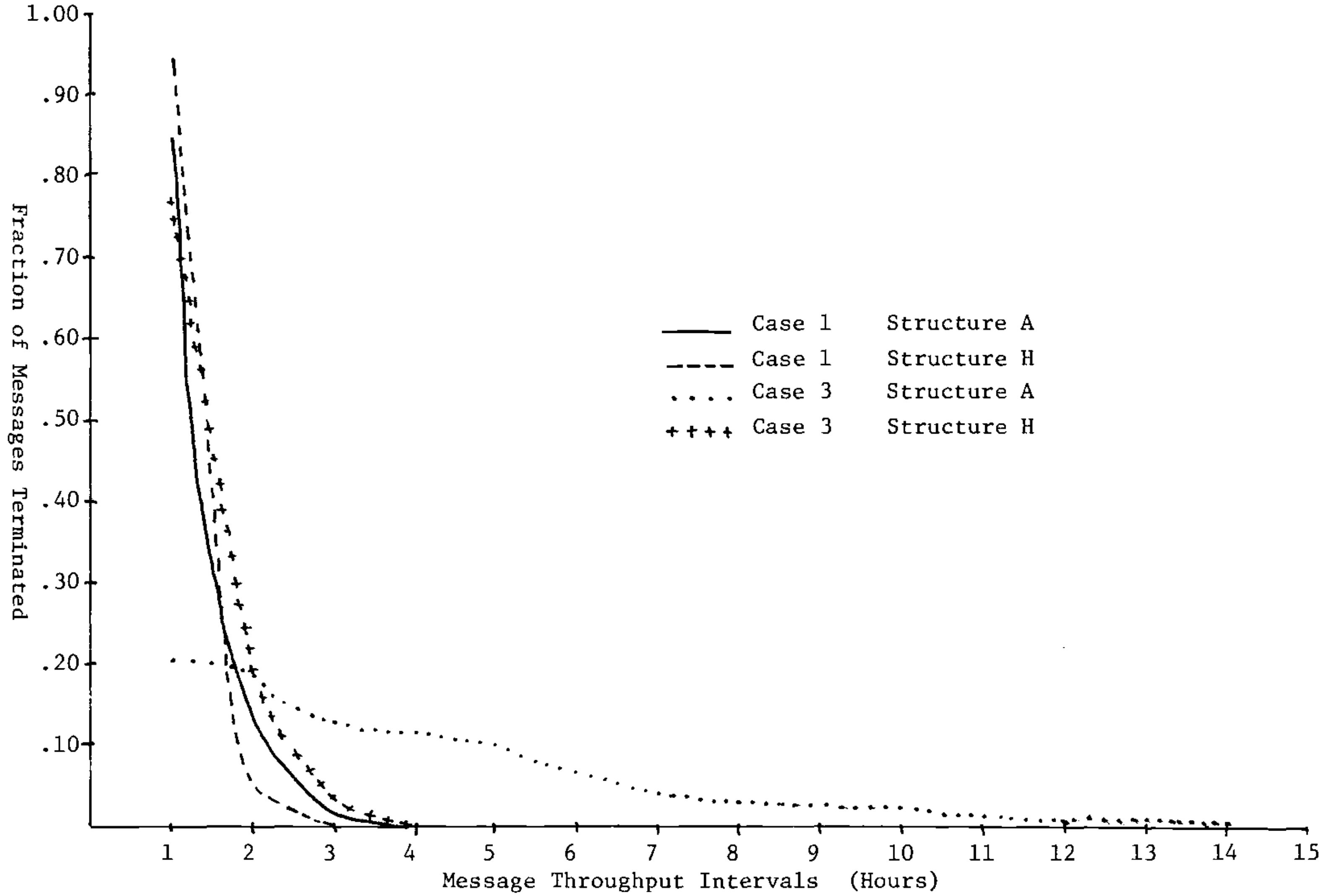


Figure 4-6. Message Throughput-Time Distributions for Structures A and H, Cases #1 and #3

Table 4-4. Summary of Message Throughput-Time Distributions

Case Number	CASE #1	CASE #2	CASE #3	CASE #4
$1/\lambda$ (min)	30	20	30	30
$1/\mu$ (min)	10	10	15	10
P_t	.50	.50	.50	.40
Organizational Structure	**Means (min)**			
A	33.17	203.83	227.38	71.52
B	30.16	118.35	166.78	55.22
C	28.22	56.91	66.90	43.93
D	26.55	50.72	74.18	40.71
E	24.21	32.24	45.89	38.21
F	23.88	31.08	42.70	33.72
G	24.06	32.34	42.40	32.06
H	23.50	33.14	43.18	32.79
Organizational Structure	**Standard Deviations (min)**			
A	29.33	198.63	213.05	68.22
B	26.23	113.92	184.65	52.36
C	25.24	55.68	58.45	41.74
D	22.54	46.44	68.54	36.76
E	20.72	29.26	42.19	38.39
F	20.59	26.85	36.31	31.07
G	20.37	27.43	34.63	28.37
H	19.61	28.62	35.23	29.35

two aspects seem to be highly correlated, some insights can be gained by analyzing them separately.

Message Queue Lengths

The message queue lengths will be analyzed in terms of their mean values, that is, in terms of mean queue lengths. These are obtained by averaging the individual mean queue lengths obtained from the computer printout according to organizational levels. Structures are characterized by having different numbers of organizational levels, as well as different numbers of positions in the levels when compared to one another. In order to make the analysis, a table summarizing the mean queue lengths (classified by organizational levels) for every structure, and under the four cases, has been constructed. Table 4-5 gives all the information required. First, the analysis will be made comparing across structures within cases. The following observations can be made on this basis:

1. The top manager's message queue lengths decrease as his span of control is decreased. This can be observed by dividing the structures into three groups: one formed by structures A and E which have the maximum spans of control for the top level (16 and 8 respectively); another group can be formed by structures C and G with spans of control of four; and, the remaining structures (B,D,F, and H) with the smallest span of control [2].

2. The mean queue lengths of the operatives (positions at the bottom level) are almost always greater than for all other organizational levels. The only exceptions are structure A under Case #2 and structure E under all cases. These structures happen to be the flattest ones, and the ones with the greatest spans of control at the top level.

3. Structure H shows the smallest overall mean queue length, with the exception of Case #2, where structure F gives the smallest overall value. The overall mean queue lengths generally decrease as the number of managers in the structure increases, but the rate of decrease is very small for structures F through H in each case.

Table 4-5. Mean Queue Lengths

CASE PARAMETERS				ORGANIZATIONAL STRUCTURES							
$1/\lambda$	$1/\mu$	P_t	Org. Level	A	B	C	D	E	F	G	H
30	10	.50	Top Mgr.	.44	.02	.05	.02	.13	.02	.03	.02
min	min		Level 2	--	.17	.17	.02	.14	.03	.01	.01
			Level 3	--	--	--	.09	--	.09	.05	.01
CASE #1			Level 4	--	--	--	--	--	--	--	.05
			Operat.	.44	.34	.24	.21	.08	.09	.11	.10
			Overall	.44	.31	.22	.16	.10	.08	.08	.07
20	10	.50	Top Mgr.	11.12	.18	.29	.14	.47	.17	.14	.11
min	min		Level 2	--	.59	.52	.04	.46	.10	.04	.03
			Level 3	--	--	--	.27	--	.25	.17	.02
CASE #2			Level 4	--	--	--	--	--	--	--	.18
			Operat.	9.38	5.12	1.83	1.55	.41	.45	.55	.59
			Overall	9.48	4.38	1.51	1.14	.43	.36	.36	.36
30	15	.50	Top Mgr.	2.72	.07	.16	.05	.38	.08	.11	.04
min	min		Level 2	--	.58	.43	.03	.45	.07	.04	.02
			Level 3	--	--	--	.24	--	.23	.13	.02
CASE #3			Level 4	--	--	--	--	--	--	--	.14
			Operat.	6.94	4.84	1.18	1.45	.31	.33	.37	.38
			Overall	6.70	4.14	.99	1.09	.36	.27	.25	.24
30	10	.40	Top Mgr.	1.24	.04	.14	.03	.36	.05	.07	.04
min	min		Level 2	--	.51	.56	.03	.59	.12	.06	.02
			Level 3	--	--	--	.26	--	.29	.13	.02
CASE #4			Level 4	--	--	--	--	--	--	--	.15
			Operat.	1.59	1.01	.52	.49	.14	.16	.18	.19
			Overall	1.57	.91	.51	.39	.29	.19	.14	.14

4. As the number of organizational levels is increased the queue lengths become more uniform and constant throughout all levels. However, the lowest level tends almost always to be the one with greater queue lengths.

Some other interesting aspects can be pinpointed as the analysis is done by comparing the different cases within structures.

1. As would be expected, Case #1 presents the set of conditions that permit the best performance of the system. The message queue lengths for Case #1 are consistently the smallest ones among cases for all structures.

2. Case #2 conditions create the largest overall queue lengths, even though Case #3 was shown earlier to yield the largest mean message throughput times.

3. Case #4 tends to yield results very close to those given by Case #1. Also, Cases #2 and #3 behave similarly.

4. When comparing between Cases #4 and #1, and between Cases #2 and #3, structure A is the one with the greatest difference in overall queue lengths. In other words, structure A is most sensitive (in terms of queue lengths) to changes in communication conditions. The same contrast is observed for the top manager's queue lengths.

Queue Waiting Times

The queue waiting times represent the total time that transactions spend waiting in line to be processed. The output of the simulation run that was used for this comparison is the average time per transaction spent in the queue. The individual results provided by the computer are grouped together in the same manner as was done for the message queue lengths analysis. A mean is obtained by organizational levels for each structure under the four cases, and the analysis is done in terms of mean queue waiting times. Table 4-6 depicts all the necessary data. Again, the analysis is presented in two parts: one considering structures within cases, and the other considering cases within structures.

1. In the overall, the more positions in the organizational

Table 4-6. Mean Queue Waiting Times

CASE PARAMETERS				ORGANIZATIONAL STRUCTURES							
$1/\lambda$	$1/\mu$	P_t	Org. Level	A	B	C	D	E	F	G	H
30 min	10 min	.50	Top Mgr.	6.64	.59	1.26	.45	2.50	.49	.72	.48
			Level 2	--	9.10	8.29	1.58	7.54	2.89	1.57	1.04
			Level 3	--	--	--	5.19	--	4.84	3.81	.97
CASE #1			Level 4	--	--	--	--	--	--	--	3.90
			Operat.	6.72	5.41	4.14	3.64	1.70	1.85	2.12	2.03
			Overall	6.71	4.10	3.98	3.11	2.27	1.94	1.78	1.60
20 min	10 min	.50	Top Mgr.	110.55	3.18	4.49	2.29	6.57	2.84	2.38	1.97
			Level 2	--	9.10	8.29	1.53	7.54	2.89	1.57	1.04
			Level 3	--	--	--	5.19	--	4.84	3.81	.97
CASE #2			Level 4	--	--	--	--	--	--	--	3.90
			Operat.	94.27	53.71	21.14	18.16	5.80	6.31	7.42	7.85
			Overall	95.23	46.35	17.89	13.69	6.39	5.49	5.44	5.32
30 min	15 min	.50	Top Mgr.	42.72	1.83	3.73	1.37	7.59	2.05	2.74	1.16
			Level 2	--	14.31	8.66	1.89	10.80	3.10	2.29	1.46
			Level 3	--	--	--	7.12	--	6.86	4.48	1.64
CASE #3			Level 4	--	--	--	--	--	--	--	4.53
			Operat.	103.86	75.24	20.55	25.72	6.28	6.82	7.44	7.68
			Overall	100.26	64.96	17.82	19.35	7.35	6.37	5.75	5.46
30 min	10 min	.40	Top Mgr.	15.23	1.08	2.73	.72	5.55	1.06	1.61	1.02
			Level 2	--	8.31	8.63	1.15	9.20	3.08	2.04	1.04
			Level 3	--	--	--	5.12	--	5.63	3.06	1.26
CASE #4			Level 4	--	--	--	--	--	--	--	3.42
			Operat.	19.47	13.05	7.50	7.07	2.69	2.86	3.14	3.31
			Overall	19.22	11.92	7.49	5.94	4.89	3.63	2.91	2.85

structures, the less mean queue waiting time. The only exception is for structures C and D under Case #3.

2. As the span of control of the top manager is decreased, the mean queue waiting time decreases. This fact is most easily observed by considering the three groups of structures (A and E; C and G; and B, D, F and H) according to span of control of top manager. Secondarily, the top manager's queue waiting time seems to depend on organizational levels. In general, the more organizational levels, the lower are the queue waiting times for a given span of control.

3. Structure E always gives the lowest queue waiting times at the operative level regardless of the case.

4. Structure H, regardless of the conditions, always gives the lowest value of overall mean queue waiting times. This tends to indicate that the more positions there are in the organization, the smaller the queue waiting times will be in general.

When making the comparisons among cases, the observations are as follows:

1. All organizational levels obtain the smallest mean queue waiting times under the conditions of Case #1. This result is consistent with that found for mean queue lengths and is consistent with expectations.

2. While for overall mean queue lengths Case #2 gave the worst results, Case #3 gives the largest overall mean queue waiting times.

In overall review of this section, it will be noticed that the first mode of comparison (i.e., comparing structures within cases) gave very similar results for queue lengths and queue waiting times. In fact, the only important difference was that the queue waiting times were more consistent (i.e., there were fewer exceptions to the observations made). However, some significant differences were found as the comparisons were made across cases. Not only were the worst cases different, but the similarities found in some cases for the queue lengths were not encountered for queue waiting times. Based on these concepts, two conclusions can summarize the discussion of message queues:

1. Organizational structures appear to influence queues (in terms of their lengths and waiting times) in a very consistent manner. That is, the reaction of the system to different structures follows the same pattern for lengths and waiting times of the message queues.

2. The conditions (or cases parameters) under which the system performs its functions appear to have different impacts upon message queue lengths and waiting times for various structures.

Personnel Utilization

In designing an organization, close attention must be given to the number of personnel that will work in it. The reason for this, of course, is cost. In addition, the cost generally depends on the level of the organization in which the person is going to work. The purpose of analyzing the personnel utilization is, therefore, to help clarify whether the positions in the organization are well utilized in terms of their time. Obviously, processing messages is not the sole activity carried out by a person working for an organization. Some of the person's time has to be devoted to activities like organizing, planning, inspecting, etc., but much of the other activities can be visualized as communications processing. An allowance could be made for this if the percentage of time spent on other activities was known. Nevertheless, our attention is concentrated on the processing of messages, and the personnel utilization was calculated on this basis.

The computer printouts provide the percentage of total time that each position is engaged in processing messages. These individual utilizations were averaged according to organizational levels, and a mean personnel utilization for each level was obtained for every

Table 4-7. Mean Personnel Utilizations

CASE PARAMETERS				ORGANIZATIONAL STRUCTURES							
$1/\lambda$	$1/\mu$	P_t	Org. Level	A	B	C	D	E	F	G	H
30	10	.50	Top Mgr.	.65	.36	.42	.37	.50	.37	.39	.37
min	min		Level 2	--	.42	.43	.18	.41	.23	.15	.13
			Level 3	--	--	--	.35	--	.36	.31	.10
CASE #1			Level 4	--	--	--	--	--	--	--	.29
			Operat.	.65	.63	.58	.57	.47	.47	.50	.49
			Overall	.66	.59	.54	.49	.45	.42	.40	.36
20	10	.50	Top Mgr.	.98	.58	.63	.59	.71	.61	.57	.57
min	min		Level 2	--	.64	.62	.29	.60	.33	.25	.23
			Level 3	--	--	--	.51	--	.51	.44	.16
CASE #2			Level 4	--	--	--	--	--	--	--	.46
			Operat.	.97	.94	.85	.85	.69	.71	.74	.74
			Overall	.97	.89	.80	.73	.66	.62	.58	.56
30	15	.50	Top Mgr.	.94	.56	.66	.55	.72	.59	.60	.57
min	min		Level 2	--	.62	.61	.25	.62	.35	.25	.21
			Level 3	--	--	--	.51	--	.51	.44	.17
CASE #3			Level 4	--	--	--	--	--	--	--	.46
			Operat.	.97	.92	.85	.87	.71	.72	.74	.74
			Overall	.96	.87	.80	.74	.68	.62	.58	.55
30	10	.40	Top Mgr.	.80	.41	.53	.43	.65	.40	.45	.41
min	min		Level 2	--	.61	.64	.24	.64	.39	.28	.22
			Level 3	--	--	--	.51	--	.53	.43	.19
CASE #4			Level 4	--	--	--	--	--	--	--	.44
			Operat.	.81	.77	.69	.69	.53	.54	.56	.56
			Overall	.81	.74	.67	.61	.57	.52	.47	.46

structure under the four sets of conditions that are being studied. Table 4-7 summarizes these results. The figures given in the table are expressed as decimal fractions (e.g., the value .65 represents 65.0%).

Looking first at the structures and comparing them within cases, the following observations can be made:

1. As would be expected, the overall personnel utilization decreases as the number of positions in the structure increases.

2. At the operative level, structure E consistently gives the smallest personnel utilization.

3. Structures A and E appear to give the most uniform mean personnel utilization across organizational levels. Structure H gives the least uniform utilizations across levels, with the mid-level managers being least utilized.

4. In general, the more levels in the organization, the less uniform the personnel utilization by levels.

5. The broader the top manager's span of control, the higher is his utilization (this again can be viewed if the structures are categorized in groups according to span of control of top manager). Secondarily, the top manager's utilization seems to depend on the number of organizational levels. With several exceptions, the more levels the lower is his utilization for a given span of control.

The different sets of conditions imposed by the cases also affect the personnel utilization. Making the analysis by cases within structures, the following points can be observed:

1. As would be expected, Case #1 consistently yields the minimum utilizations for all structures.

2. Cases #2 and #3 yield the largest utilizations for all structures, and the differences across these two cases are practically negligible.

3. The performance at each level is in general consistent within cases. That is, Case #1 provides the lowest utilizations for all levels. Likewise, the comparison between Cases #2 and #3 for all levels shows a great deal of similarity in the figures.

4. Case #4 could be seen as providing an intermediate set of conditions as it gives figures that fall between the other cases. This finding is also consistent with all other analyses made previously.

In general, structure A is not very suitable for cases #2, #3, and #4, since the level of utilization of the personnel is extremely high. If these percentages of time are devoted to the processing of messages, there will be practically no time for other types of activities. It is impossible, however, to state an "optimum" percentage of time that a person should devote to communication. This depends on the other activities that are also to be associated with the organizational position itself, and can vary greatly from one position to another.

Personnel-Related Costs

As was previously stated, the implications of cost may be a crucial constraint on the design of the organization. Therefore this factor should be added to the analysis and comparison of the different possible structural forms that can be designed above the 16 bottom-level positions.

In order to compare the costs of the various structures, some arbitrary assumptions must be made concerning the relative compensation received by the various managers in each structure. It seems reasonable to assume that the compensation received by a manager would be related to his level in the organization measured from the top of the structure. Therefore, for the sake of this analysis the following assumptions were made:

1. The top level manager in each organization receives the same compensation (S), regardless of structure.

2. Managers on each level receive 75% as much as managers at the next higher level.

3. Operatives receive 30% of top manager's compensation, regardless of structure.

Notice that these assumptions do not attempt to consider the span of control at any managerial level as a determinant of compensation. Though span of control may be a factor in reality, it is not likely to be as dominant as organizational level. Other factors that would be expected to affect executive compensation but are not considered here, include seniority, specific assigned duties and responsibilities, and past performance. Also, the term "compensation" should be viewed as including all variable personnel-related costs, such as fringe benefits and office space, as well as basic salary.

Based on these assumptions, the following table can be constructed.

Table 4-8. Assumptions on Personnel Compensation

Organization Level	Compensation per Position
Top Manager	S
2nd Level	(.75)S
3rd Level	(.56)S*
4th Level	(.42)S**
Operatives	(.30)S

* $(.75)^2S = (.56)S$
** $(.75)^3S = (.42)S$

To construct a table of costs, the figures given in Table 4-8 are multiplied by the number of positions at each level, according to the structure. The costs obtained are shown in Table 4-9. The figures can be viewed as the personnel-related costs incurred based upon the arbitrary formula. It may seem intuitive that in moving from structure A to H, the cost should consistently increase since the total number of managers is increasing. However, this is not actually what happens under our assumptions. Structure F shows a smaller cost than structure E because structure E has more highly paid managers (all of them except the top manager at the second structural level). The same situation exists in the comparison of structures G and H.

It is also interesting to note that the ratio of the total number of managers in the largest structure (H) versus the smallest structure (A) is 15/1; the ratio of total costs, however, for the most expensive structure (G) to the least expensive structure (A) is only 13.28/5.80, or approximately 2.3/1, based on the assumptions given. This suggests that there may be more latitude in designing organizational structures from a cost standpoint than may typically be assumed.

Summary of Results

A separate analysis of each one of the evaluation parameters has been presented. It is convenient now to make a summary of all the results so that a complete picture can be used as the basis for comparison. In Table 4-10 the overall results have been summarized for each structure and case (the table is divided into two parts to improve readability). Table 4-11 shows the same information expressed in a different manner. In that table, the values of the criteria are expressed as multiples of the smallest (best) value on each row from Table 4-10. Analyzing these two tables the following observations can be made:

Table 4-9. Personnel-Related Costs

Organization Level	ORGANIZATIONAL STRUCTURES							
	A	B	C	D	E	F	G	H
Top Manager	S	S	S	S	S	S	S	S
Level 2	---	1.50S	3.00S	1.50S	6.00S	1.50S	3.00S	1.50S
Level 3	---	---	---	2.24S	---	4.48S	4.48S	2.24S
Level 4	---	---	---	---	---	---	---	3.36S
Operatives	4.80S	4.80S	4.80S	4.80S	4.80S	4.80S	4.80S	4.80S
Overall	5.80S	7.30S	8.80S	9.54S	11.80S	11.78S	13.28S	12.90S

Table 4-10. Overall Summary of Results

CASE PARAMETERS				ORGANIZATIONAL STRUCTURES							
$1/\lambda$	$1/\mu$	P_t	Criterion*	A	B	C	D	E	F	G	H
30	10	.50	MTT	33.17	30.16	28.22	26.55	24.21	23.88	24.06	23.50
min	min		SDTT	29.33	26.23	25.24	22.54	20.72	20.59	20.37	19.61
			MQL	0.43	0.31	0.22	0.16	0.10	0.08	0.08	0.07
CASE #1			MQWT	6.71	5.00	4.00	3.11	2.27	1.94	1.78	1.60
			MPU	0.66	0.59	0.54	0.49	0.45	0.42	0.40	0.36
			COST (x S)	5.80	7.30	8.80	9.54	11.80	11.78	13.28	12.90
20	10	.50	MTT	203.83	118.35	56.91	50.72	32.24	31.08	32.34	33.14
min	min		SDTT	198.63	113.92	55.68	46.45	29.26	26.85	27.43	28.62
			MQL	9.48	4.39	1.51	1.14	0.43	0.36	0.36	0.36
CASE #2			MQWT	95.23	46.35	17.90	13.70	6.39	5.49	5.44	5.32
			MPU	0.97	0.89	0.80	0.73	0.66	0.62	0.58	0.56
			COST (x S)	5.80	7.30	8.80	9.54	11.80	11.78	13.28	12.90

CASE PARAMETERS				ORGANIZATIONAL STRUCTURES							
$1/\lambda$	$1/\mu$	P_t	Criterion	A	B	C	D	E	F	G	H
30 min	15 min	.50	MTT	227.38	116.78	66.90	74.18	45.89	42.70	42.40	43.18
			SDTT	213.05	184.65	58.45	68.54	42.19	36.31	34.63	35.23
			MQL	6.97	4.14	0.99	1.09	0.36	0.27	0.25	0.24
CASE #3			MQWT	100.26	64.96	17.82	19.36	7.35	6.37	5.75	5.46
			MPU	0.96	0.87	0.70	0.74	0.68	0.62	0.58	0.55
			COST (x S)	5.80	7.30	8.80	9.54	11.80	11.78	13.28	12.90
30 min	10 min	.40	MTT	71.52	55.22	43.93	40.71	38.21	33.72	32.06	32.79
			SDTT	68.22	52.36	41.74	36.76	38.39	31.07	28.37	29.35
			MQL	1.57	0.91	0.51	0.39	0.29	0.19	0.14	0.14
CASE #4			MQWT	19.22	11.92	7.49	5.94	4.89	3.63	2.91	2.85
			MPU	0.81	0.74	0.67	0.61	0.57	0.52	0.47	0.46
			COST (x S)	5.80	7.30	8.80	9.54	11.80	11.78	13.28	12.90

*MTT = Mean Throughput Time
SDTT = Standard Deviation Throughput Time
MQL = Mean Queue Length
MQWT = Mean Queue Waiting Time
MPU = Mean Personnel Utilization
COST = Personnel-Related Costs

Table 4-11. Summary of Results with Values Expressed as Multiples of the Minimum on Each Row*

CASE PARAMETERS				ORGANIZATIONAL STRUCTURES							
$1/\lambda$	$1/\mu$	P_t	Criterion**	A	B	C	D	E	F	G	H
30	10	.50	MTT	1.41	1.29	1.20	1.13	1.03	1.02	1.03	----
min	min		SDTT	1.49	1.34	1.29	1.15	1.06	1.05	1.04	----
			MQL	6.46	4.57	3.27	2.45	1.49	1.21	1.13	----
CASE #1			MQWT	4.19	3.13	2.50	1.94	1.42	1.21	1.11	----
			MPU	1.82	1.64	1.50	1.35	1.24	1.15	1.09	----
			COST	----	1.26	1.52	1.64	2.03	2.03	2.29	2.22
20	10	.50	MTT	6.55	3.81	1.83	1.63	1.04	----	1.04	1.07
min	min		SDTT	7.40	4.24	2.07	1.73	1.09	----	1.02	1.07
			MQL	26.62	12.32	4.24	3.19	1.20	----	1.02	1.01
CASE #2			MQWT	17.92	8.72	3.37	2.58	1.20	1.03	1.02	----
			MPU	1.74	1.60	1.44	1.32	1.19	1.11	1.05	----
			COST	----	1.26	1.52	1.64	2.03	2.03	2.29	2.22

CASE PARAMETERS			ORGANIZATIONAL STRUCTURES								
$1/\lambda$	$1/\mu$	P_t	Criterion	A	B	C	D	E	F	G	H
30 min	15 min	.50	MTT	5.36	2.75	1.58	1.75	1.08	1.01	----	1.02
			SDTT	6.15	5.33	1.69	1.98	1.22	1.05	----	1.02
			MQL	28.39	17.54	4.19	4.62	1.51	1.15	1.05	----
CASE #3			MQWT	18.36	11.89	3.26	3.54	1.35	1.17	1.05	----
			MPU	1.74	1.57	1.44	1.33	1.22	1.13	1.05	----
			COST	----	1.26	1.52	1.64	2.03	2.03	2.29	2.22
30 min	10 min	.40	MTT	2.23	1.72	1.37	1.27	1.19	1.05	----	1.02
			SDTT	2.40	1.84	1.47	1.30	1.35	1.10	----	1.03
			MQL	11.13	6.44	3.60	2.77	2.09	1.35	1.02	----
CASE #4			MQWT	6.74	4.18	2.62	2.08	1.71	1.27	1.02	----
			MPU	1.78	1.62	1.48	1.33	1.26	1.15	1.03	----
			COST	----	1.26	1.52	1.64	2.03	2.03	2.29	2.22

*All figures expressed as multiples of the smallest value on each row in Table 4-10.

**MTT = Mean Throughput Time
SDTT = Standard Deviation Throughput Time
MQL = Mean Queue Length
MQWT = Mean Queue Waiting Time
MPU = Mean Personnel Utilization
COST = Personnel-Related Costs

1. For the conditions of Case #1, the differences in the values of the criteria between structures are relatively small. Therefore, when the set of circumstances is the one given in Case #1, the criterion on which to select the "optimal" structure probably should be cost, unless there is a special reason for "optimizing" any other parameter.

2. Under the conditions imposed by Cases #2 and #3, structures A and B become extremely ineffective in terms of all the operational criteria. For these cases the other six structures (C,D,E,F,G and H) vary within reasonable ranges, but generally tend to perform better as more managerial positions are added to the organization.

3. For Case #4, though the range of values between structures A and H is wider than for Case #1, structures A and B may still be considered as reasonable candidates.

4. In general, the more complex the structure in terms of having more positions, the less sensitive it becomes to changes in the conditions as can be realized by looking at structures F, G and H.

5. For all cases, the four largest organizational structures (E, F,G and H) give very close results. Structures C and D appear to perform similarly, and structures A and B tend to form a different group. Therefore, in terms of queueing performance, the structures could be classified in three different groups. The least effective (structures A and B), the intermediate (structures C and D), and the most effective (structures E,F,G and H).

6. The performance criteria associated with message queues seem to be the most sensitive to change of structure. This can be seen most easily in Table 4-11.

7. Overall mean personnel utilization is the criterion that is least affected by the differences in case parameters. This is partially due to the fact that values of this criterion are limited to the 0-1 interval, whereas the other criteria have no upper limit.

Figures 4-7 to 4-10 show in a graphical form the data presented in Table 4-11.

The overall results of the study are reasonable and tend to agree with what could be inferred from common sense. The simulations, however, help to clarify and pinpoint important features in the analysis

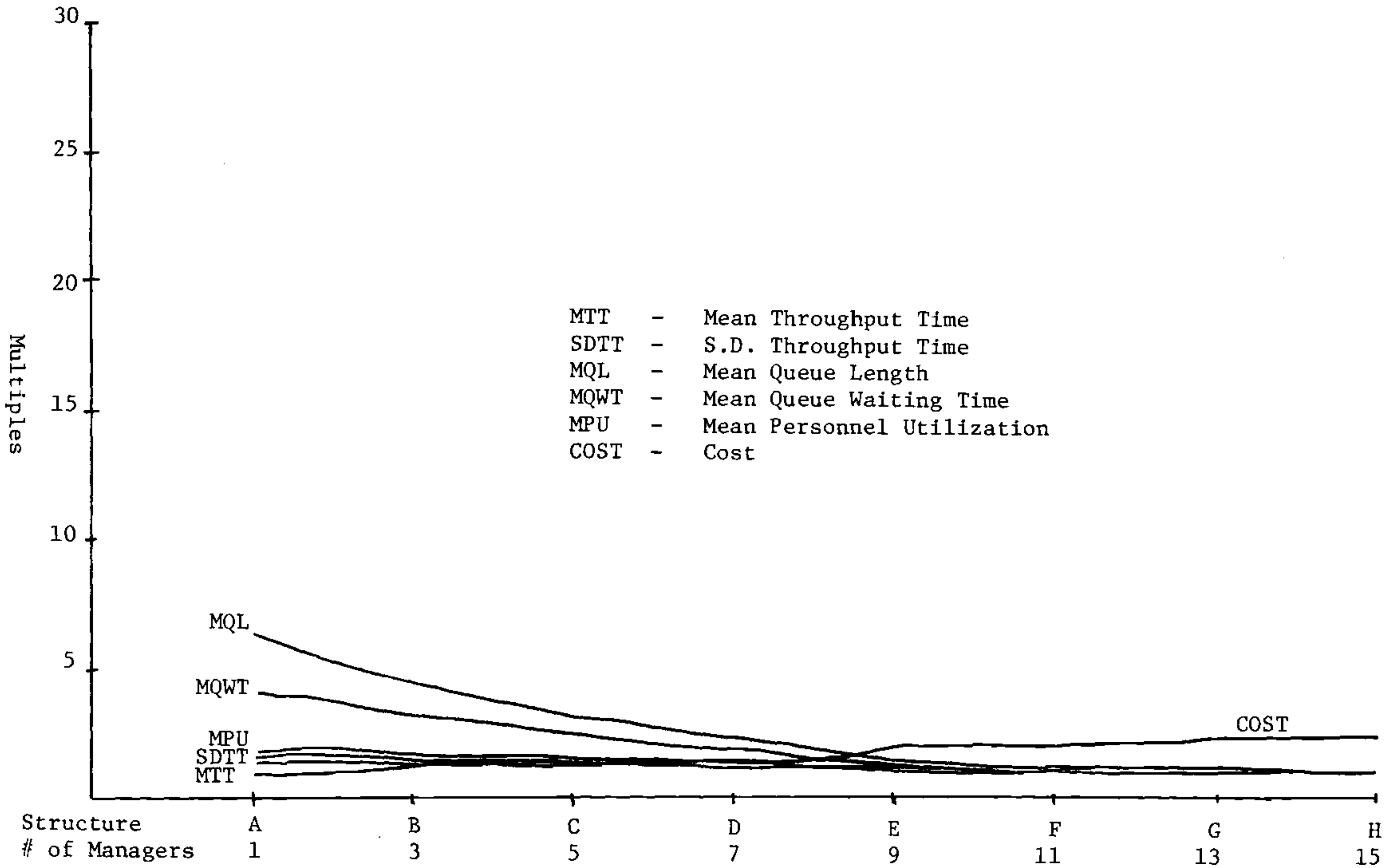


Figure 4-7. Summary of Results (Expressed as Multiples of the Minimum on Each Row) for Case #1

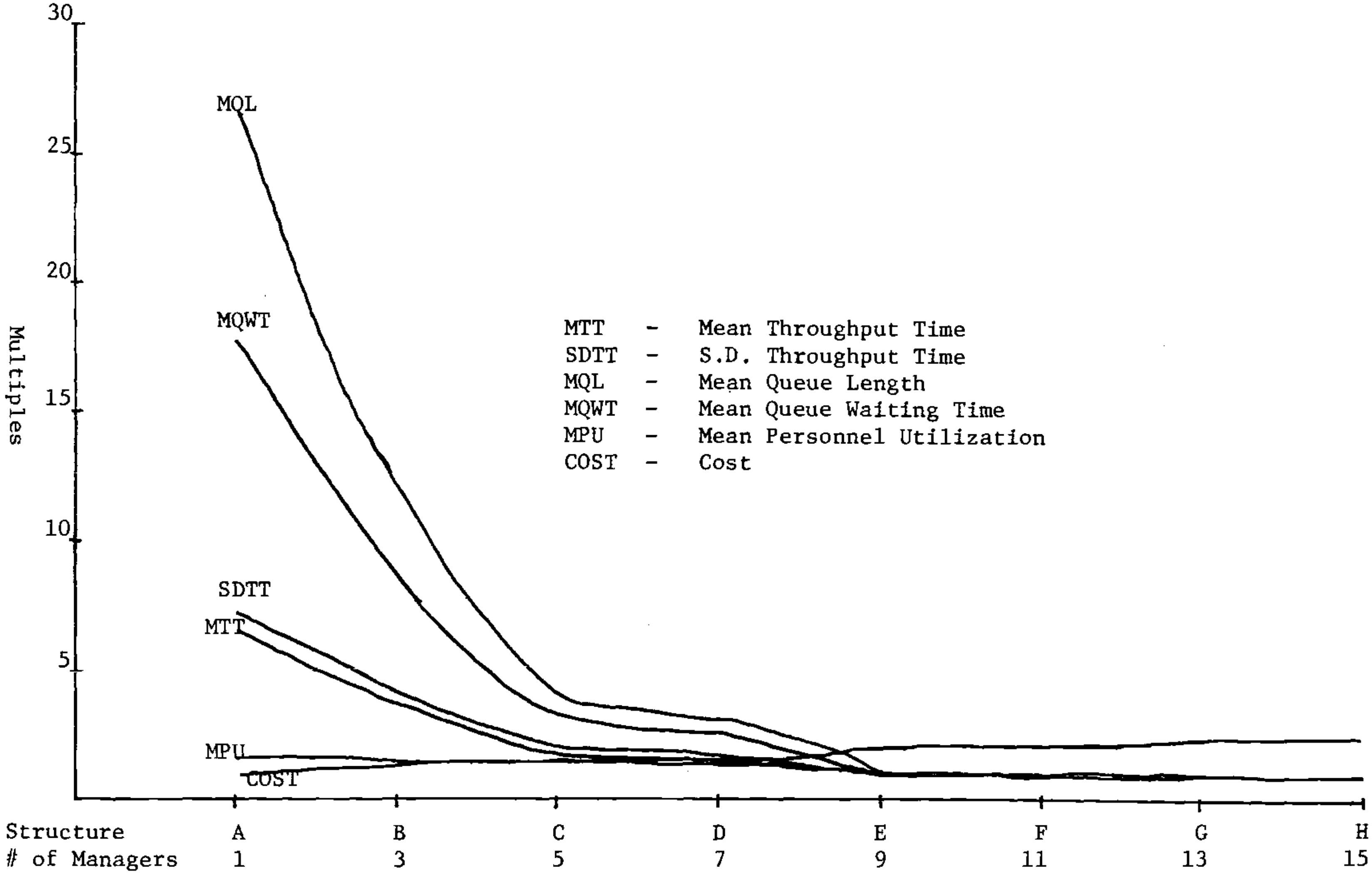


Figure 4-8. Summary of Results (Expressed as Multiples of the Minimum on Each Row) for Case #2

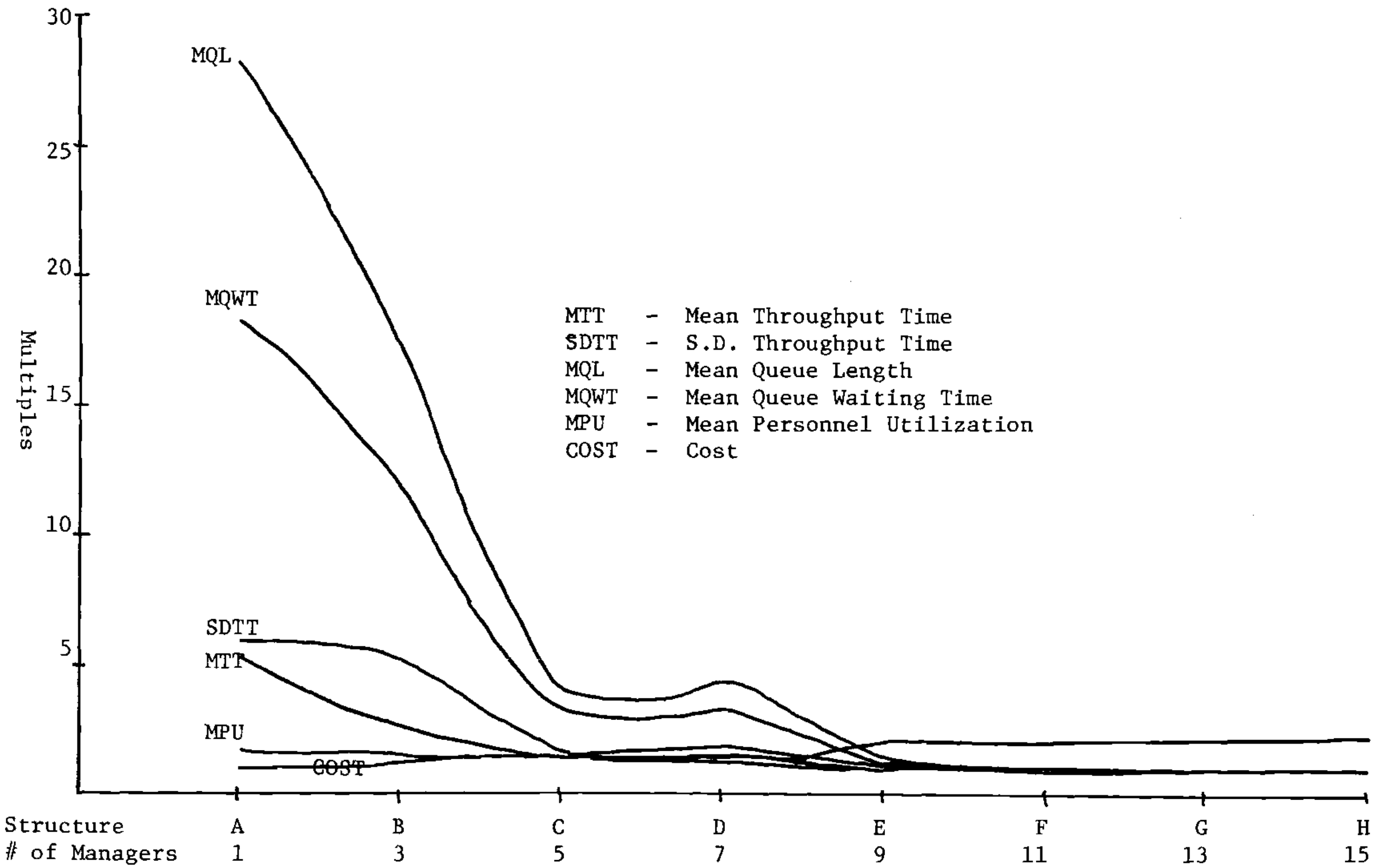


Figure 4-9. Summary of Results (Expressed as Multiples of the Minimum on Each Row) for Case #3

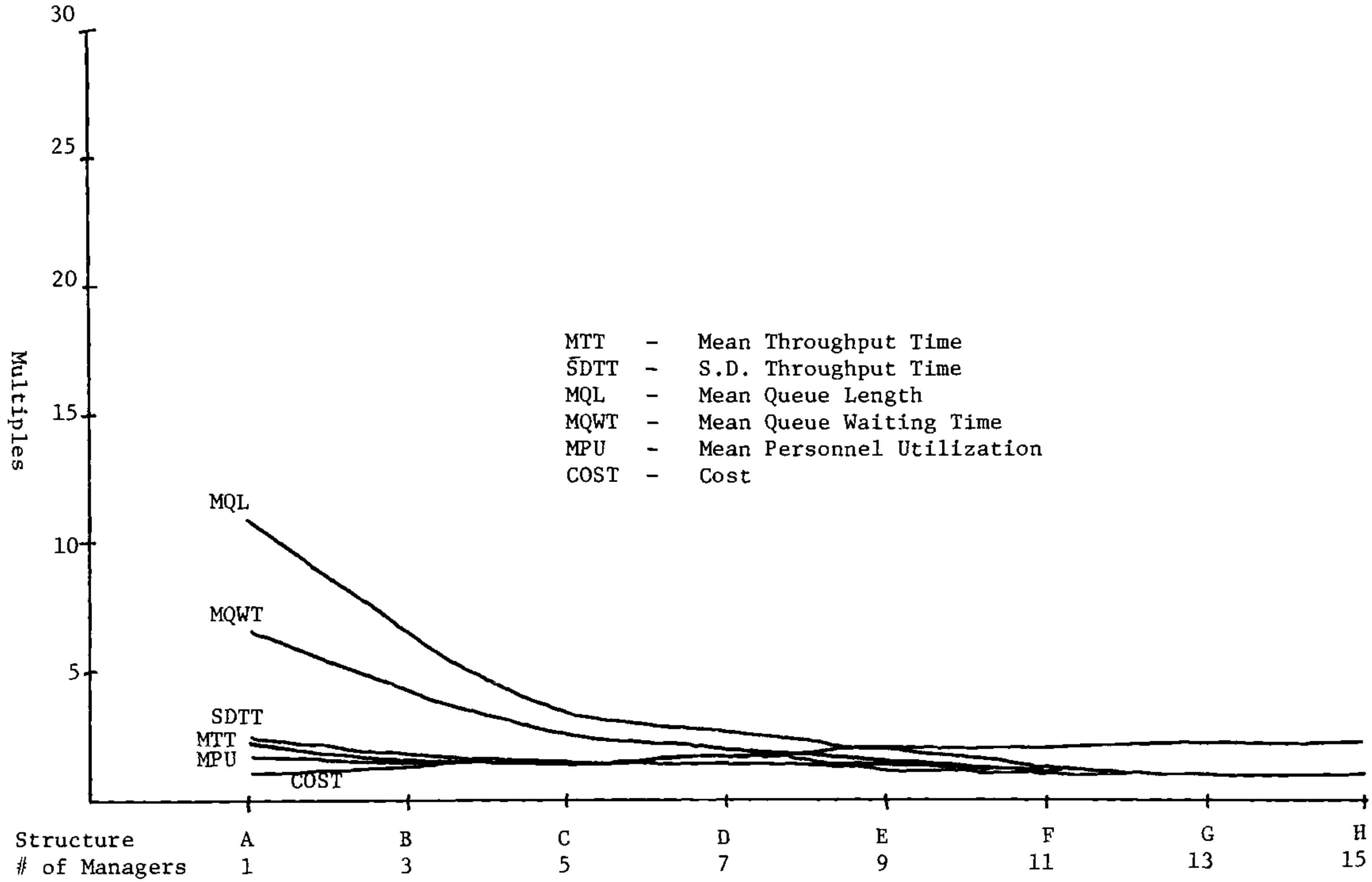


Figure 4-10. Summary of Results (Expressed as Multiples of the Minimum on Each Row) for Case #4

and design of organizations as communication systems.

There are, however, many different types of organizations, (i.e., manufacturing organizations, service organizations, etc.) and each type may require special emphasis on a certain characteristic of its function. For instance, a real organization may be engaged in a type of activity that requires very rapid message throughput with relatively little concern for personnel costs. This could be the case, for example, in an intensive care unit in a hospital. Thus, it is impossible to determine a single overall optimum structure. But the same procedure for at least the concepts used for this study can be adapted to whatever conditions or characteristics may be encountered in reality in any given organization.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The overall objective of the study, as stated in Chapter I, was to demonstrate the modelling and simulation analysis of organizational structures as communication queueing systems. Once again, some points brought to mind in the literature survey (Chapter II) should be noted. Systems theory is a relatively new methodology that is becoming predominant in the study and analysis of organizations. A conceptual model of organizational structures as communication queueing systems has been developed to provide a method of analysis based on concepts of systems theory. In addition, a procedure for a computer simulation of organizational structures has been illustrated. Finally, the simulation methodology was employed to evaluate and analyze the communication performance of a simple, hypothetical organization. This was done under several alternative structural arrangements and sets of communication parameter values.

Some assumptions were made for the purpose of this study; however, most of them can easily be relaxed,especially with the use of the computer simulation language GPSS.

The results obtained illustrate the usefulness of this sort of analysis to provide an understanding of the overall performance of an organization in terms of its communication activities, as its characteristic features (span of control, number of hierarchical levels, etc.) are changed.

Two research questions were addressed in the analysis of the simulation results for the hypothetical organization:

I. What are the relative sensitivities of the various queueing performance criteria to changes in (a) organizational structure, and (b) communication parameter values? In this regard, the conclusions can be summarized as follows:

1. Queue lengths and queue waiting times were most sensitive to both types of changes.

2. Personnel utilization was least sensitive, partially because it is restricted to the 0-1 interval.

3. In general, the structures with the smallest numbers of managers were most sensitive to changes in communication parameters (most easily overloaded). Also, once a given size of structure was exceeded, in this case a structure containing 9 managers (Structure E), most of the queueing performance criteria became very insensitive to further increases in organizational size.

4. Changes in the different communication parameters did not affect all performance criteria to a consistent degree. For example, increasing the message generation rate (Case #2) yielded the worst performance in terms of overall queue lengths, whereas decreasing the message processing rate (Case #3) yielded the worst results in terms of the mean and standard deviation of message throughput times and the overall queue waiting times.

II. What specific aspects of the organizational structure have key impacts on performance? The results lead to the conclusion that:

1. Span of control has a primary impact on an organization level-by-level basis.

2. The number of levels in the organizational structure has a secondary impact.

A very broad span of control at any level of an organizational structure can create a bottleneck such that queue lengths, queue waiting times, and personnel utilizations are very high for some levels of that structure but low for other levels (consider structures B and E in Tables 4-5, 4-6, and 4-7).

Recommendations

The insight gained by means of this simulation study has proved it to be a worthwhile methodology for organizational analysis. Indeed, the experiments conducted in this study via simulation would have been extremely difficult, if not impossible, to conduct in a field setting. On the other hand, an organization consists of many different activities other than communication, from which it can be analyzed. Therefore, further development of organizational simulation in general is suggested as a useful technique to expand the knowledge in this field.

It was mentioned above that most of the assumptions made in this study can be relaxed. The relaxation of these assumptions may permit the simulation to represent more accurately the characteristics and activities of a real organization; in this regard, some specific extensions to this study are recommended:

1. Messages originating at the upper levels may have a higher priority to be processed than those generated at the bottom levels. Therefore, an allowance can be made to permit the establishment of priority queueing, as well as interruptions in message processing caused by the arrival of higher priority messages.

2. The use of staff can also be incorporated into the features being modeled. The effect of the characteristics of staff personnel in generating, processing and transferring messages on the performance of the organization would be an interesting aspect to test. Various policies for the use of staff personnel could be tested.

3. Different message generation rates, processing rates and termination probabilities can also be allowed according to organizational level. This is also a characteristic

normally encountered in reality due to the different type and complexity of problems handled at different organizational levels.

4. In this study, middle managers are not allowed to generate messages, but only to process them. As was mentioned in Chapter III, all message processing at middle levels can be visualized as ultimately originating as a communication from above or below. However, it would be worthwhile to test the performance of the organization if messages are also allowed to be generated at middle levels.

5. Communications are simulated in this study in a formal fashion; that is, messages are only transferred to a position directly connected to the sender. In reality, communication very frequently does not follow formal lines. Messages are sent between positions that are not directly connected within the organizational structure. This characteristic could also be included in an extension to the study.

6. In many real world situations, messages are communicated from a single individual to an entire group through an announcement, a multiple-copy memo, etc. For example, a manager may communicate to his entire group of subordinates at one time. This form of communication could be modelled and its impact examined.

7. The current study implicitly assumes that all communications are in written form. It was not necessary for both the sender and receiver to simultaneously devote their attention to the communication as would be required in face-to-face communication. The full range of communication media should be modelled.

8. Finally, an application of this simulation technique to the analysis of a real organization is proposed as an extension of the study.

APPENDIX

```
V/6000                                        CRM GPSS V/6000   VER. 1.2

*LOC    OPERATION   A,B,C,D,E,F,G,H,I,J        COMMENTS

        SIMULATE
        GENERATE    30,15        CREATE TRANSACTION MANAGER 1
 MAA1   QUEUE       1            QUEUE FOR MANAGER 1
        SEIZE       1            GET THE POSITION
        DEPART      1            LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     1            FREE MANAGER 1
        TRANSFER    .5,TTA,AAA1  TERMINATE OR CONTINUE
*
 MAA2   QUEUE       2            QUEUE FOR MANAGER 2
        SEIZE       2            GET THE POSITION
        DEPART      2            LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     2            FREE MANAGER 2
        TRANSFER    .5,TTA,AAA2  TERMINATE OR CONTINUE
*
 MAA3   QUEUE       3            QUEUE FOR MANAGER 3
        SEIZE       3            GET THE POSITION
        DEPART      3            LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     3            FREE MANAGER 3
        TRANSFER    .5,TTA,AAA3  TERMINATE OR CONTINUE
*
        GENERATE    30,15        CREATE TRANSACTION POSITION 1
 POS1   QUEUE       21           QUEUE FOR POSITION 1
        SEIZE       21           GET THE POSITION
        DEPART      21           LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     21           FREE POSITION 1
        TRANSFER    .5,TTA,BBB1  TERMINATE OR CONTINUE
*
        GENERATE    30,15        CREATE TRANSACTION POSITION 2
 POS2   QUEUE       22           QUEUE FOR POSITION 2
        SEIZE       22           GET THE POSITION
        DEPART      22           LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     22           FREE POSITION 2
        TRANSFER    .5,TTA,BBB2  TERMINATE OR CONTINUE
*
        GENERATE    30,15        CREATE TRANSACTION POSITION 3
 POS3   QUEUE       23           QUEUE FOR POSITION 3
        SEIZE       23           GET THE POSITION
        DEPART      23           LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     23           FREE POSITION 3
        TRANSFER    .5,TTA,BBB3  TERMINATE OR CONTINUE
*
        GENERATE    30,15        CREATE TRANSACTION POSITION 4
 POS4   QUEUE       24           QUEUE FOR POSITION 4
        SEIZE       24           GET THE POSITION
        DEPART      24           LEAVE INITIAL QUEUE
        ADVANCE     10,7         PROCESS TRANSACTION
        RELEASE     24           FREE POSITION 4
        TRANSFER    .5,TTA,BBB4  TERMINATE OR CONTINUE
*
```

```
*LOC    OPERATION   A,B,C,D,E,F,G,H,I,J        COMMENTS
        GENERATE    30,15          CREATE TRANSACTION POSITION 5
POS5    QUEUE       25             QUEUE FOR POSITION 5
        SEIZE       25             GET THE POSITION
        DEPART      25             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     25             FREE POSITION 5
        TRANSFER    .5,TTA,BBB5  TERMINATE OR CONTINUE
*
        GENERATE    30,15          CREATE TRANSACTION POSITION 6
POS6    QUEUE       26             QUEUE FOR POSITION 6
        SEIZE       26             GET THE POSITION
        DEPART      26             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     26             FREE POSITION 6
        TRANSFER    .5,TTA,BBB6  TERMINATE OR CONTINUE
*
        GENERATE    30,15          CREATE TRANSACTION POSITION 7
POS7    QUEUE       27             QUEUE FOR POSITION 7
        SEIZE       27             GET THE POSITION 7
        DEPART      27             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     27             FREE POSITION 7
        TRANSFER    .5,TTA,BBB7  TERMINATE OR CONTINUE
*
        GENERATE    30,15          CREATE TRANSACTION POSITION 8
POS8    QUEUE       28             QUEUE FOR POSITION 8
        SEIZE       28             GET THE POSITION
        DEPART      28             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     28             FREE POSITION 8
        TRANSFER    .5,TTA,BBB8  TERMINATE OR CONTINUE
*
        GENERATE    30,15          CREATE TRANSACTION POSITION 9
POS9    QUEUE       29             QUEUE FOR POSITION 9
        SEIZE       29             GET THE POSITION
        DEPART      29             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     29             FREE POSITION 9
        TRANSFER    .5,TTA,BBB9  TERMINATE OR CONTINUE
*
        GENERATE    30,15          CREATE TRANSACTION POSITION 10
POS10   QUEUE       30             QUEUE FOR POSITION 10
        SEIZE       30             GET THE POSITION
        DEPART      30             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     30             FREE POSITION 10
        TRANSFER    .5,TTA,BBB10 TERMINATE OR CONTINUE
*
        GENERATE    30,15          CREATE TRANSACTION POSITION 11
POS11   QUEUE       31             QUEUE FOR POSITION 11
        SEIZE       31             GET THE POSITION
        DEPART      31             LEAVE INITIAL QUEUE
        ADVANCE     10,7           PROCESS TRANSACTION
        RELEASE     31             FREE POSITION 11
        TRANSFER    .5,TTA,BBB11 TERMINATE OR CONTINUE
```

```
*LOC    OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS
*
        GENERATE   30,15        CREATE TRANSACTION POSITION 12
POS12   QUEUE      32           QUEUE FOR POSITION 12
        SEIZE      32           GET THE POSITION
        DEPART     32           LEAVE INITIAL QUEUE
        ADVANCE    10,7         PROCESS TRANSACTION
        RELEASE    32           FREE POSITION 12
        TRANSFER   .5,TTA,BBB12 TERMINATE OR CONTINUE
*
        GENERATE   30,15        CREATE TRANSACTION POSITION 13
POS13   QUEUE      33           QUEUE FOR POSITION 13
        SEIZE      33           GET THE POSITION
        DEPART     33           LEAVE INITIAL QUEUE
        ADVANCE    10,7         PROCESS TRANSACTION
        RELEASE    33           FREE POSITION 13
        TRANSFER   .5,TTA,BBB13 TERMINATE OR CONTINUE
*
        GENERATE   30,15        CREATE TRANSACTION POSITION 14
POS14   QUEUE      34           QUEUE FOR POSITION 14
        SEIZE      34           GET THE POSITION
        DEPART     34           LEAVE INITIAL QUEUE
        ADVANCE    10,7         PROCESS TRANSACTION
        RELEASE    34           FREE POSITION 14
        TRANSFER   .5,TTA,BBB14 TERMINATE OR CONTINUE
*
        GENERATE   30,15        CREATE TRANSACTION POSITION 15
POS15   QUEUE      35           QUEUE FOR POSITION 15
        SEIZE      35           GET THE POSITION
        DEPART     35           LEAVE INITIAL QUEUE
        ADVANCE    10,7         PROCESS TRANSACTION
        RELEASE    35           FREE POSITION 15
        TRANSFER   .5,TTA,BBB15 TERMINATE OR CONTINUE
*
        GENERATE   30,15        CREATE TRANSACTION POSITION 16
POS16   QUEUE      36           QUEUE FOR POSITION 16
        SEIZE      36           GET THE POSITION
        DEPART     36           LEAVE INITIAL QUEUE
        ADVANCE    10,7         PROCESS TRANSACTION
        RELEASE    36           FREE POSITION 16
        TRANSFER   .5,TTA,BBB16 TERMINATE OR CONTINUE
*
TTA     TABULATE   TTSS
        TERMINATE  1
TTSS    TABLE      M1,0,15,20    TABLE FOR TIME SPENT IN THE SYSTEM
AAA1    TRANSFER   FN,MMM1      TRANSFER TRANSACTION
*
AAA2    TRANSFER   FN,MMM2      TRANSFER TRANSACTION
*
AAA3    TRANSFER   FN,MMM3      TRANSFER TRANSACTION
*
BBB1    TRANSFER   FN,TTT1      TRANSFER TRANSACTION
*
BBB2    TRANSFER   FN,TTT2      TRANSFER TRANSACTION
*
BBB3    TRANSFER   FN,TTT3      TRANSFER TRANSACTION
```

```
*LOC    OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS
*
 BBB4   TRANSFER   FN,TTT4     TRANSFER TRANSACTION
*
 BBB5   TRANSFER   FN,TTT5     TRANSFER TRANSACTION
*
 BBB6   TRANSFER   FN,TTT6     TRANSFER TRANSACTION
*
 BBB7   TRANSFER   FN,TTT7     TRANSFER TRANSACTION
*
 BBB8   TRANSFER   FN,TTT8     TRANSFER TRANSACTION
*
 BBB9   TRANSFER   FN,TTT9     TRANSFER TRANSACTION
*
 BBB10  TRANSFER   FN,TTT10    TRANSFER TRANSACTION
*
 BBB11  TRANSFER   FN,TTT11    TRANSFER TRANSACTION
*
 BBB12  TRANSFER   FN,TTT12    TRANSFER TRANSACTION
*
 BBB13  TRANSFER   FN,TTT13    TRANSFER TRANSACTION
*
 BBB14  TRANSFER   FN,TTT14    TRANSFER TRANSACTION
*
 BBB15  TRANSFER   FN,TTT15    TRANSFER TRANSACTION
*
 BBB16  TRANSFER   FN,TTT16    TRANSFER TRANSACTION
*
 MMM1   FUNCTION   RN1,D2
.5,MAA2/1,MAA3
*
 MMM2   FUNCTION   RN1,D10
.1,MAA1/.2,MAA3/.3,POS1/.4,POS2/.5,POS3/.6,POS4/.7,POS5/.8,POS6
.9,POS7/1,POS8
*
 MMM3   FUNCTION   RN1,D10
.1,MAA1/.2,MAA2/.3,POS9/.4,POS10/.5,POS11/.6,POS12/.7,POS13/.8,POS14
.9,POS15/1,POS16
*
 TTT1   FUNCTION   RN1,D8
.125,MAA2/.25,POS2/.375,POS3/.5,POS4/.625,POS5/.75,POS6/.875,POS7
1,POS8
*
 TTT2   FUNCTION   RN1,D8
.125,MAA2/.25,POS1/.375,POS3/.5,POS4/.625,POS5/.75,POS6/.875,POS7
1,POS8
*
 TTT3   FUNCTION   RN1,D8
.125,MAA2/.25,POS1/.375,POS2/.5,POS4/.625,POS5/.75,POS6/.875,POS7
1,POS8
*
 TTT4   FUNCTION   RN1,D8
.125,MAA2/.25,POS1/.375,POS2/.5,POS3/.625,POS5/.75,POS6/.875,POS7
1,POS8
*
 TTT5   FUNCTION   RN1,D8
```

```
*LOC    OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS
.125,MAA2/.25,POS1/.375,POS2/.5,POS3/.625,POS4/.75,POS6/.875,POS7
1,POS8
*
 TTT6   FUNCTION    RN1,D8
.125,MAA2/.25,POS1/.375,POS2/.5,POS3/.625,POS4/.75,POS5/.875,POS7
1,POS8
*
 TTT7   FUNCTION    RN1,D8
.125,MAA2/.25,POS1/.375,POS2/.5,POS3/.625,POS4/.75,POS5/.875,POS6
1,POS8
*
 TTT8   FUNCTION    RN1,D8
.125,MAA2/.25,POS1/.375,POS2/.5,POS3/.625,POS4/.75,POS5/.875,POS6
1,POS7
*
 TTT9   FUNCTION    RN1,D8
.125,MAA3/.25,POS10/.375,POS11/.5,POS12/.625,POS13/.75,POS14
.875,POS15/1,POS16
*
 TTT10  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS11/.5,POS12/.625,POS13/.75,POS14
.875,POS15/1,POS16
*
 TTT11  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS10/.5,POS12/.625,POS13/.75,POS14
.875,POS15/1,POS16
*
 TTT12  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS10/.5,POS11/.625,POS13/.75,POS14
.875,POS15/1,POS16
*
 TTT13  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS10/.5,POS11/.625,POS12/.75,POS14
.875,POS15/1,POS16
*
 TTT14  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS10/.5,POS11/.625,POS12/.75,POS13
.875,POS15/1,POS16
*
 TTT15  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS10/.5,POS11/.625,POS12/.75,POS13
.875,POS14/1,POS16
*
 TTT16  FUNCTION    RN1,D8
.125,MAA3/.25,POS9/.375,POS10/.5,POS11/.625,POS12/.75,POS13
.875,POS14/1,POS15
*
        START       6000,,1000    RUN FOR 6000 MESSAGES
```

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